THE ROYAL AERONAUTICAL SOCIETY WAS FOUNDED IN 1866

AUGUST, 1944
No. 404
Vol. XLVIII.

MONTHLY
PRICE
5/-

The Journal of The Royal Aeronautical Society

which is incorporated The Institution of Aeronautical Engineers

Edited for the Council by Capt. J. LAURENCE PRITCHARD, Hon. Fellow

CONTENTS FOR AUGUST, 1944

Monthly Notices

Aerodynamic Features of German Aircraft *Morgan & Smelt*

Reviews

The ROYAL AERONAUTICAL SOCIETY, 4, Hamilton Place, W.1

Telephones Grosvenor 3515 (3 lines)

YOU NEED THESE BOOKS

ESSENTIAL METALLURGY FOR ENGINEERS

By A. C. VIVIAN, B.A. (Cantab.), D.Sc. (London), Assoc. R.S.M., M.Inst.Met. Lecturer in Metallurgy at the R.A.F. School of Aeronautical Engineering. In this book the reader is given a short account of the essentials in modern control over the properties of metallic materials. It is a book devised on new lines, aiming at the correct, complete but easy understanding by technicians of the diverse metallic alloys of engineering. **8s. 6d.** net.

THE FLIGHT TESTING OF PRODUCTION AIRCRAFT

By J. A. CROSBY WARREN, M.A. (Cantab.), A.F.R.Ae.S. With a Foreword by the Rt. Hon. Harold Balfour. An authoritative manual for test pilots, maintenance unit pilots and squadron pilots of the R.A.F., Ferry and Airline Pilots, private owners and all aeronautical and reference libraries. No other work on the flight testing of aircraft is available. **8s. 6d.** net.

FLIGHT AND AIRFRAMES FOR THE AIRCRAFT FITTER

By D. O. BISHOP, B.Sc. (Eng.), and P. A. BOSANQUET, B.Sc. In this work there are many original features, one of particular interest being the section on Hydraulics. The authors have described how an aircraft hydraulic system is built in such a way that those who wish to master the principles can do so without taking a lengthy theoretical course. **10s. 6d.** net.

APPLIED D.R. NAVIGATION

By J. H. CLOUGH-SMITH, B.Sc. (Lond.). With a Foreword by Captain J. C. KELLY ROGERS, O.B.E. This important book shows how an aeroplane is navigated in actual practice, and to that extent supplements the information given in the standard textbooks. More than 100 examples with full solutions are included. **6s.** net.

AIRCRAFT ELECTRICAL ENGINEERING

By F. G. SPREADBURY. A book by an experienced engineer, designed for the use of advanced technicians in aircraft electrical equipment and engineering industries. More than two hundred illustrations are included. **21s.** net.

PITMAN'S 39, PARKER STREET, KINGSWAY

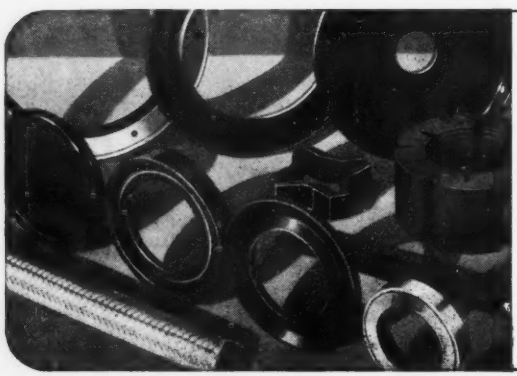
TREFOIL

BAKELITE **PLASTICS**

REGD. TRADE MARKS

Pioneers in the Plastics World

BAKELITE LIMITED, 18 GROSVENOR GARDENS, LONDON, S.W.1

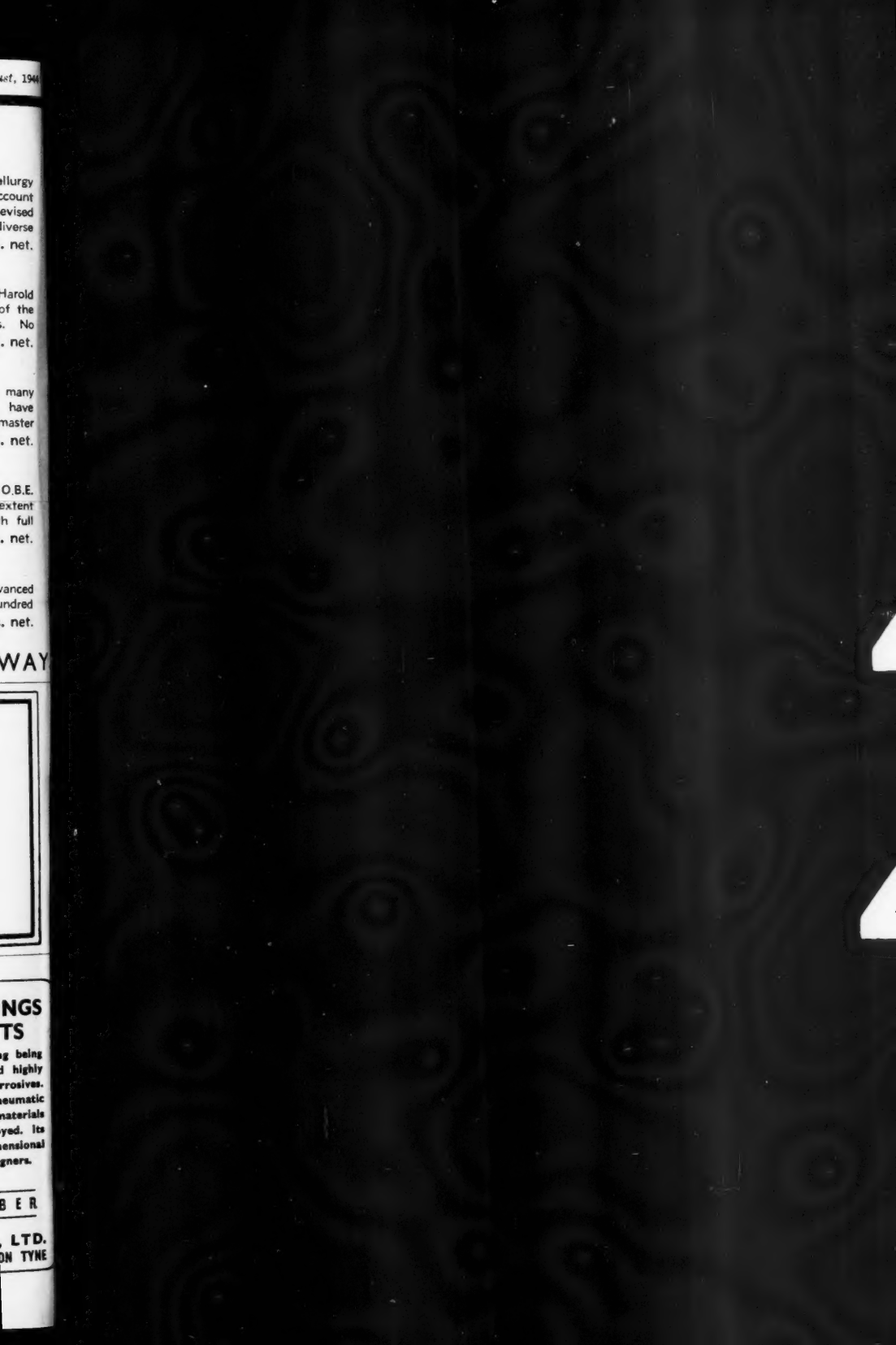


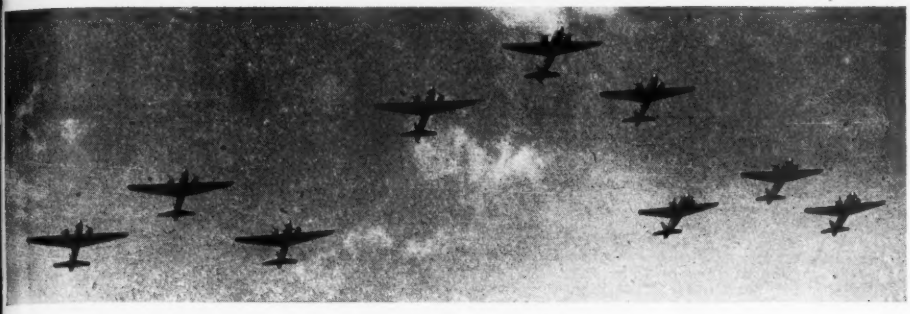
HYDRAULIC PACKINGS SEALS • GASKETS

GACO is ideal for hydraulic sealing being grainless, resilient, non-porous, and highly resistant to oils, fuels and chemical corrosives. It is widely used in the hydraulic and pneumatic control systems of aircraft where only materials of the highest grade can be employed. Its unequalled surface finish and dimensional accuracy are well-known to all designers.

SYNTHETIC GACO RUBBER

GEORGE ANGUS & CO., LTD.
OIL SEAL WORKS, NEWCASTLE UPON TYNE





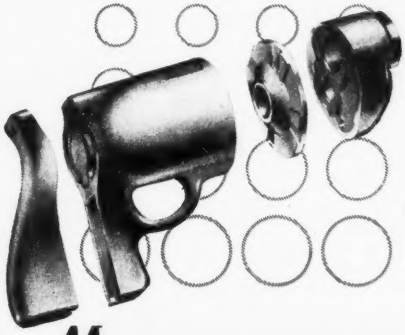
WELLINGTONS HIT BALKAN RAIL JUNCTION

"Wellingtons are noted for their precision bombing in the Mediterranean area, so that a good strike on the railway yards at Plovdiv will almost certainly have cut another of Hitler's few supply lines running through the Balkans."

Daily Telegraph and Morning Post 19-4-44

VICKERS-ARMSTRONGS LTD
Head Office: VICKERS HOUSE · BROADWAY · LONDON · S·W·1

The Lightest Structural Metal



MAGNUMINIUM
MAGNESIUM BASE ALLOYS

THE LIGHTEST CASINGS FOR ELECTRIC TOOLS

The ultra-lightness and strength of **MAGNUMINIUM** magnesium base alloys makes them most desirable for use in the manufacture of portable electric tools, domestic appliances and a host of other products all subject to frequent lifting and handling. In the operation of reciprocating parts of machinery Magnuminium overcomes starting inertia, decreases power consumption and permits increase of speed. Magnuminium has excellent machining properties and can generally be fabricated by methods similar to those used in other metals. Full technical details available from the Sales Department.

MAGNESIUM CASTINGS & PRODUCTS LTD · SLOUGH

ELEKTRON
the pioneer
MAGNESIUM ALLOYS

Drop Stamped forgings in Elektron Magnesium alloys

● *Sole Producers and Proprietors of the Trade Mark "Elektron":* MAGNESIUM ELEKTRON LIMITED, Abbey House, London, N.W.1 ● *Licensed Manufacturers Castings & Forgings:* STERLING METALS LIMITED, Northey Road, Foleshill, Coventry ● *Castings:* THE BIRMINGHAM ALUMINIUM CASTING (1903) COMPANY LIMITED, Birmid Works, Smethwick, Birmingham ● J. STONE & COMPANY LIMITED, Deptford, London, S.E.14 ● *Sheet, Extrusions, Forgings & Tubes:* JAMES BOOTH & CO. LIMITED, Argyle Street Works, Nechells, Birmingham, 7 ● *Sheet Extrusions, Etc.:* BIRMETALS LIMITED, Woodgate, Quinton, Birmingham ● *Suppliers of Magnesium and "Elektron" Metal for the British Empire:* F. A. HUGHES & CO. LIMITED, Abbey House, Baker Street, London, N.W.1

WARWICK AVIATION CO. LTD.

AERONAUTICAL ENGINEERS AND CONSTRUCTORS

Contractors to the Air Ministry, War Office and Admiralty

DESIGNERS OF AIRCRAFT

OFFICE : SALTISFORD, WARWICK
'Phone : Warwick 693

The Cream of the World's Fighters

The Rolls-Royce Company, with the Merlin and the new Griffon engines, have surpassed even their great reputation by maintaining in the stratosphere the cream of the world's fighters . . . . Engine development has, of course, played an important part in all this. (*Daily Telegraph*)

ROLLS-ROYCE

AERO ENGINES

THE SIGNIFICANCE OF HIDUMINIUM* TO YOUR INDUSTRY

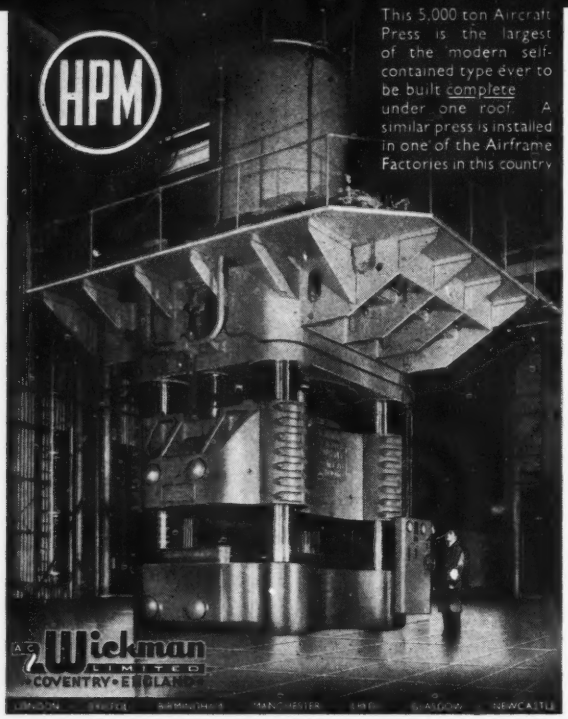
THE characteristics of light metals impel imaginative thinking. Whatever you manufacture — aeroplanes, ships, road transport vehicles, railway rolling stock, machinery or household appliances, building or electrical equipment—**HIDUMINIUM** aluminium alloys will play an indispensable part in solving the mechanical and structural problems of the future. A new Company—Hiduminium Applications Ltd.,—has been formed to collaborate with designers and constructors in every industry to secure the best use of Hiduminium alloys. Further information will be sent on request.

★*Light weight and high strength, high thermal and electrical conductivity · high resistance to corrosion, workability · ease of fabrication, non-toxic and non-magnetic · excellent appearance.*

HIDUMINIUM APPLICATIONS LTD.

ALUMINIUM ALLOYS FARNHAM ROAD · SLOUGH · BUCKS.

HIGH DUTY ALLOYS LTD · REYNOLDS TUBE Co LTD · REYNOLDS ROLLING MILLS LTD


HPM
This 5,000 ton Aircraft Press is the largest of the modern self-contained type ever to be built complete under one roof. A similar press is installed in one of the Airframe Factories in this country
A.E. Wickman LIMITED
COVENTRY • ENGLAND

HYDRAULIC PRESS

specially designed for the rubb pad process of forming me aircraft parts are manufactur in the following standard sizes:-

Tonnage	1000	2500	2500	500
Pad Size	60″ × 36″	96″ × 48″	96″ × 48″	168 × 50
Max. No. of Loading Tables	2	2	4	4

H.P.M. FASTRAVERSE HYDRAULIC PRESSES

are also manufactured for numerous other applications

For particulars apply to Sole Agents and Engineering Representatives :-

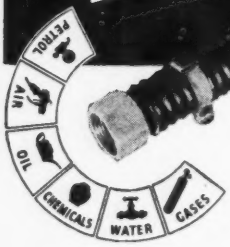
A.E. Wickman LIMITED
• COVENTRY • ENGLAND •

FLEXATEX

NON-RUBBER *flexible* HOSE

A Product of Organised Research

WILKINSON PRODUCT



TYPES FOR A WIDE RANGE OF FLUIDS OR GASES NOW BEING PRODUCED IN SIZES FROM ¼″ TO 4″ DIAMETER

No compromise with old ideas — Flexatex is something new and better. New in construction, supply and assembly. Unique design gives better relative performance than any other type. Constructed from materials to suit operating conditions. Can be cut by user to precise requirements. Fitting with end connections and installation can be carried out on site by untrained operator. Standardisation has ensured use in conjunction with A.G.S. parts.

THE MANUAL OF TECHNICAL DATA ON FLEXATEX

Applications from all over the country are being received for this interesting and practical treatise. Gives useful technical data on Flexatex, together with full instructions on its applications and some remarks on its construction. Bona fide enquirers are invited to apply for the Manual. If details of fluids or gases to be conveyed are provided, specific information will also be supplied.

WILKINSON RUBBER LINATEX LTD · FRIMLEY ROAD · CAMBERLEY · SURREY

Tel: Camberley 1595 Also in Canada, Australia, South Africa, U.S.A., etc.

Self-sealing couplings

For use in aircraft or other hydraulic piping systems.

Lockheed-Avery self-sealing couplings can be uncoupled under pressure, and recoupled, without loss of contents and without trapping air.

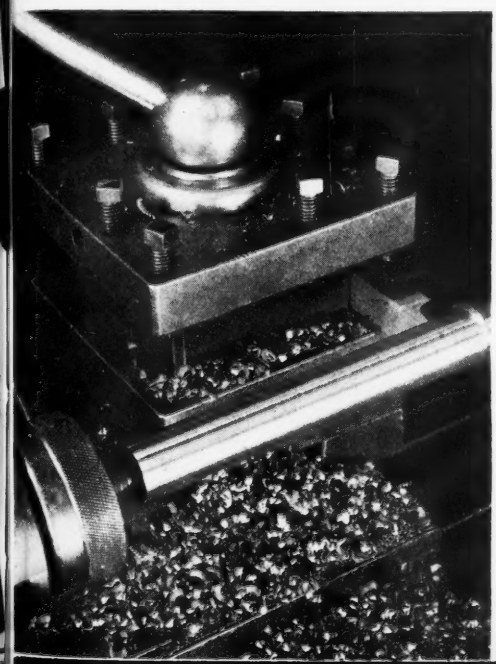
They are of the greatest value where sectionalised construction is used, as they facilitate assembly, whilst overhauls necessitating the changing of engines, or hydraulic or other units, are greatly simplified and speeded up.

The coupling is of double value when it is used in conjunction with the highly developed Lockheed - Avery hose.

AUTOMOTIVE PRODUCTS COMPANY LTD., ENGLAND.

LOCKHEED AVERY

Fully patented



FIRTH-VICKERS

FREE MACHINING STAINLESS STEELS

Now available in

STAINLESS IRON (F.C.I.)

STAINLESS STEEL (F.C.S.)

"STAYBRITE" F.D.P.

FIRTH-VICKERS STAINLESS STEELS LTD SHEFFIELD

THESE FERODO PRODUCTS MAKE NEWS . .

In the grim stress of air battle the reliability of each part of the machine may spell success or disaster. For the whole is only as efficient as the smallest component.

It is with the knowledge of the functioning of these vital parts that Ferodo Limited build a range of products for aircraft construction such as clutch discs, brake linings, bushes and washers, possessing special characteristics and made to exacting limits. You are invited to consult us where materials are needed for specific requirements when the long experience of our Technical Staff will gladly be placed at your service, without obligation.

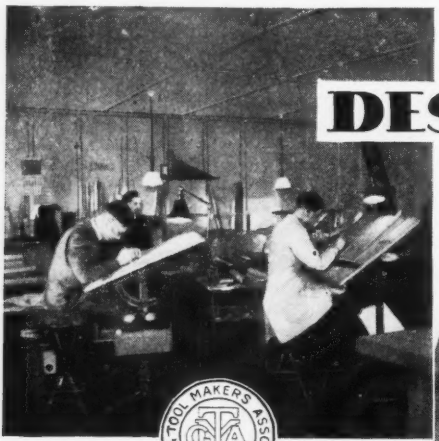
SBAC

FERODO

PRODUCTS FOR AIRCRAFT CONSTRUCTION

REGD. TRADE MARK FERODO

FERODO LIMITED · CHAPEL-EN-LE-FRITH



Production for Victory

DESIGNING *the* TOOLS

THAT WILL FINISH THE JOB..

JIG & TOOL MAKERS ASSOCIATION GAUGE

Specialists in

JIGS & FIXTURES
PRESS TOOLS
AIRCRAFT ASSEMBLY JIGS & REFERENCE GAUGES
CAPSTAN LATHE WORK
HEAT TREATMENT
SMALL ASSEMBLY HAND TOOLS

Leytonstone JIG & TOOL Co. Ltd

FULLY A.I.D. APPROVED

606 HIGH ROAD, LEYTON, LONDON, E.10. Tel: Leytonstone 5027/3 Grams: Leytool, Leyton

In my car

I'll expect a performance that will make pre-war standards look silly! Better fuels will be matched by still better engines, with dead weight cut out by the use of light alloys. That will apply to chassis and body-work too—the great technical advances in the use of these new metals make it inevitable. This is one more reason why 'International' are so proud to be makers of the highest grade aluminium alloys for every conceivable purpose.

International Alloys Ltd

SLOUGH, BUCKS

TELEPHONE: SLOUGH 23212 INTAL TELEGRAMS: INTALLOYD SLOUGH

DOWTY

Undercarriage and Hydraulic Equipment

DOWTY EQUIPMENT LIMITED

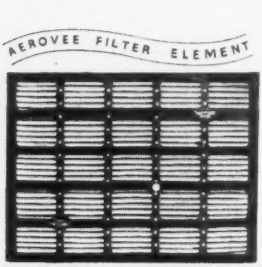
AIR FILTRATION *for* AIRCRAFT

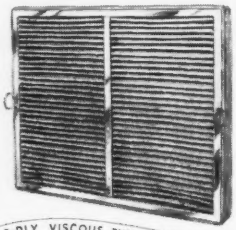
". . . problems have been overcome by two types of filter which we have been producing in great numbers—the Vokes Aerovee and the Vokes Three-ply.

The Aerovee is a dry type filter . . . It is made in five layers; two of wire gauze between which there are two layers of fabric with a centre layer of special filtering material. These layers are stitched together and are then corrugated into deep folds, so that in relation to the air inlet an enormous filtering surface is created . . . It is part of the standard equipment of the Hurricane, Spitfire and the Defiant fighters, and of the Wellington I.c., the Manchester and Halifax I bombers (to name but a few types of aircraft) . . . capacity in c.f.m. ranges between 560 and 3185 . . .

The Vokes Three-ply is a viscous type filter. It comprises two layers of wire-mesh gauze between which is a layer of fabric acting as an oil-retaining agent . . . The Three-ply is fitted (chiefly) to air-cooled engines and is standardised on the Beaufighter, the Beaufort, Blenheim, the Stirling, Albermarle, and Halifax II. It is also used on the American Boston, Maryland and Lockheed Hudson III, IV. (In all, about fifty types of aircraft are fitted with one or other of these filters). Really remarkable results have been achieved . . . types of engines that were worn out after twenty to fifty hours and often less were still worth reconditioning after two hundred hours flying . . . "

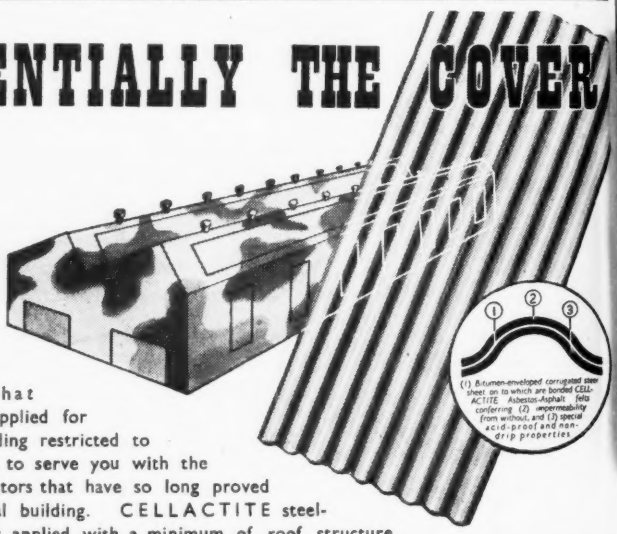
From an article in "Flight" (Feb. 24th, 1944 by C. G. VOKES, A.M.I.Mech.E., A.F.R.Ae.S., M.S.A.E., M.I.A.E. Managing Director, VOKES LTD., LONDON, S.W.





¶ VOKES AIR FILTERS ARE ALSO FITTED TO MANY AERO ENGINE TEST BEDS

Still ESSENTIALLY THE COVER for ESSENTIAL BUILDINGS


1
2
3
(1) Bitumen-enveloped corrugated steel sheet on to which are bonded CELLACTITE Asbestos-Asphalt felts conferring (2) impermeability from without, and (3) special acid-proof and non-drip properties

A wise control decrees that CELLACTITE may still be supplied for essential work. Thus, with building restricted to national needs, we are still here to serve you with the roofing, side sheeting and ventilators that have so long proved ideal for every sort of industrial building. CELLACTITE steel-cored, asbestos-asphalt is quickly applied with a minimum of roof structure and labour. It cannot crack or break either during transport or after erection. It needs no after attention, giving permanent protection without painting, even when subjected to corrosive conditions. May we quote or supply full reference information ?

CELLACTITE & BRITISH URALITE LTD.
Terminal House, 52 Grosvenor Gardens, London, S.W.1
'Phone: SLOane 5127 (4 lines) 'Grams: Cellactite, Sowest, London
Works: Higham, Kent

CELLACTITE

TAS/CL.301

Everything depends on Accuracy

SMITH'S
AIRCRAFT INSTRUMENTS

***Do** aluminium die-castings provide thin sections — smooth surfaces — close dimensional accuracy?*

THE photograph clearly illustrates the excellent foundry properties possessed by **HIDUMINIUM** aluminium alloys and their eminent suitability for the production of high strength die-castings. Provided care is taken to adapt the design of a component to satisfy the basic requirements of die-casting, the user is assured of close dimensional limits, smooth surfaces, the reduction of machining and finishing operations to a minimum, and castings of good ductility and high strength combined with lightness. Further information available on request to the Sales Department.

HIDUMINIUM ALUMINIUM ALLOYS

HIGH DUTY ALLOYS LIMITED SLOUGH

'Last night... so much depended on —

Rotax Ltd.
London, N.W. 10

ROTAX MAGNETOS

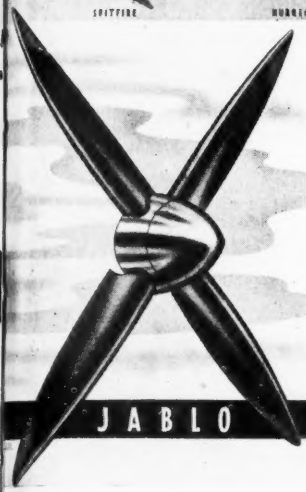
VARIABLE PITCH PROPELLERS

in Service with the Royal Air Force and the Fleet Air Arm

MAKERS OF
BIRSO
TRADE MARK
NON-FERROUS
MACHINED PARTS
and CASTINGS for
AIRCRAFT

Fully Approved by Admiralty & A.I.D

T. M. BIRKETT & Sons, Ltd
HANLEY - STAFFS
Telegrams: BIRKETT, HANLEY. Telephone: STOKE-ON-TRENT 21444



JABLO PROPELLER BLADES

The performance of Jablo Blades on Britain's finest aircraft including the Halifax Spitfire, Hurricane, Beaufighter and Wellington has earned them their reputation as "The best in the world."

THE MAJORITY OF OPERATIONAL FIGHTER AIRCRAFT ARE EQUIPPED WITH JABLO PROPELLER BLADES . . .

Bigger bomb loads in war . . .
Bigger pay loads in peace!

JABLO PROPELLERS LIMITED

The Pioneers of Laminated Plastics

22, OLD QUEEN STREET, LONDON, S.W.1

SIR W. G.
ARMSTRONG WHITWORTH
AIRCRAFT LIMITED
BRANCH OF HAWKER SIDDELEY AIRCRAFT Co. Ltd.

Designers & Constructors of the Whitley Heavy Bomber

Once in the sights . . .

. . . the enemy aircraft is doomed. The air-gunner presses a button and knows from experience that the Hymatic compressed air system that actuates the gun-firing mechanism will not fail.

Hymatic compressed air equipment is used with equal success for other vital controls in aircraft, ships and vehicles, as well as for engine starting, and this highly developed equipment will be available for these and other peacetime services.

The outstanding development, by Hymatic engineers, of small capacity air systems, suggests many possible new applications, and the makers gladly offer to share their knowledge and practical experience with those who are considering the use of compressed air in fresh fields.

Basic 'HYMATIC' *developments include small capacity Air Compressors for pressures up to* 800 *lbs., Electro-pneumatic Controls, Air-actuated Mechanisms, Oil and Water Separators, and Air Starting Equipment.*

Hymatic

COMPRESSED AIR EQUIPMENT

THE HEYWOOD COMPRESSOR COMPANY LIMITED · REDDITCH · WORCS

HC 58

. . . Facts about

'PERSPEX'

Registered Trade Mark

ACRYLIC RESIN SHEET

The ideal material for the production of difficult shapes. Available in a wider range of sizes and thicknesses than any other transparent synthetic resin material.

ICI

IMPERIAL CHEMICAL INDUSTRIES LTD.

Sales Offices at: Mill Hill, London, N.W.7; Oldbury, near Birmingham; Alderley Edge, Cheshire; Bristol; York; Newcastle-on-Tyne; Leicester; Bradford; Cardiff; Sheffield; Glasgow; Belfast; Dublin.

P.142

THE Model 7 Universal AvoMeter is the world's most widely used combination electrical measuring instrument. It provides 50 ranges of readings and is guaranteed accurate to B.S. first grade limits on D.C. and A.C. from 25 to 100 cycles. It is self-contained, compact and portable, simple to operate and almost impossible to damage electrically. It is protected by an automatic cut-out against damage through severe overload and is provided with automatic compensation for variations in ambient temperature.

The AvoMeter is one of a useful range of "Avo" electrical testing instruments which are maintaining on active service and in industry the "Avo" reputation for an unexcelled standard of accuracy and dependability — in fact, a standard by which other instruments are judged.

Orders can now only be accepted which bear a Government Contract Number and Priority Rating

Sole Proprietors and Manufacturers:

AUTOMATIC COIL WINDER & ELECTRICAL EQUIPMENT CO., LTD.

Winder House, Douglas St., London, S.W.1 *Vic. 3404*

THE
WHIRLWIND
FIGHTER-BOMBER

★ ★ ★

Designed and Constructed by
WESTLAND
AIRCRAFT
LIMITED

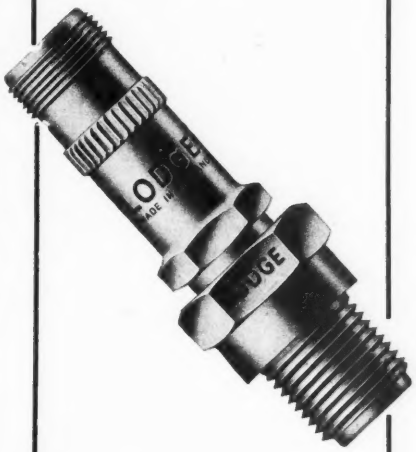
★ HOBSON INDUCTION PRESSURE (BOOST) CONTROLS

★ HOBSON-PENN AUTOMATIC MIXTURE CONTROLS

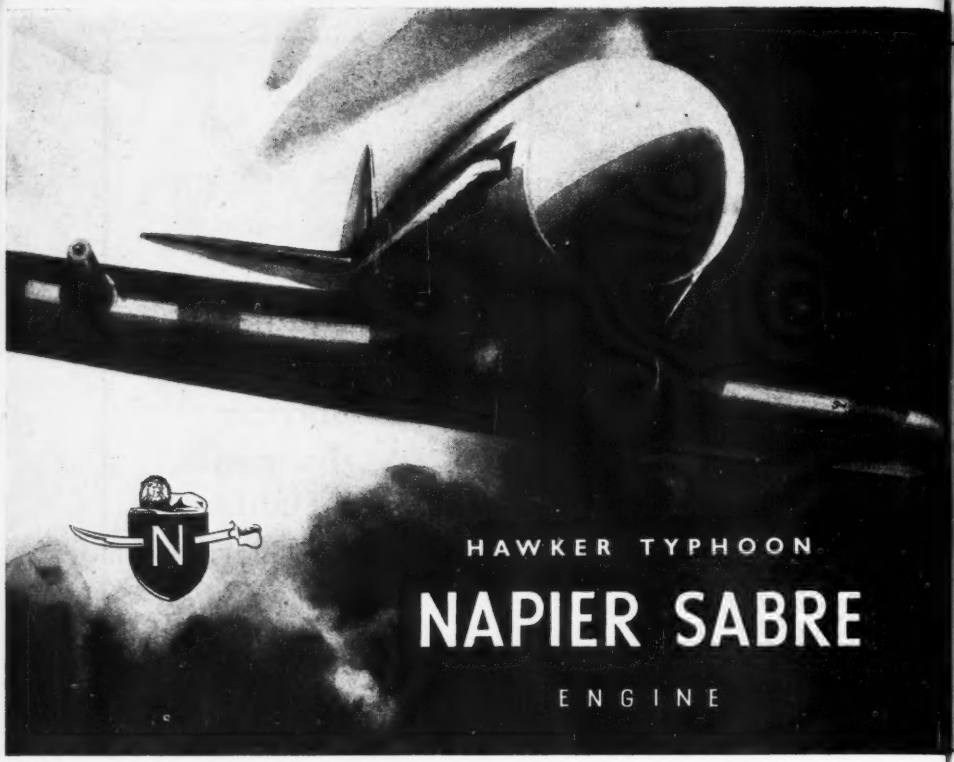
★ HOBSON PILOT'S COCKPIT CONTROLS

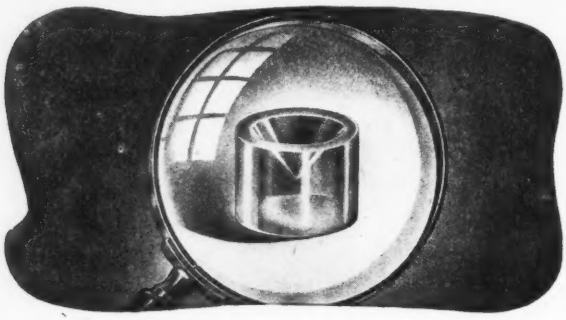
FOR ALL TYPES OF AERO ENGINES
HOBSON
(REGD. TRADE MARK)
Master Control Carburetters
H. M. HOBSON (AIRCRAFT & MOTOR) COMPONENTS LTD.

The World's
finest and fastest aircraft
Spitfire
Seafire
Mosquito
Mustang
Hurricane
Lancaster
Halifax
Barracuda
are powered by the famous
Rolls-Royce "Merlin"
engines
fitted with
LODGE
PLUGS



Made by
LODGE PLUGS LTD.
Rugby





"V" TYPE
SANWEST
INSTRUMENT BEARINGS

A Jewel Beyond Price

A Kingdom has been offered for a horse . . . but even greater, the time of emergency, was the value of having available the process for the production of "SANWEST" jewels when supplies of other instrument bearings were cut off almost overnight. The "SANWEST" V Type bearings, which have been produced since those wild days, have given complete satisfaction under the most arduous conditions.

In 3 sizes ; 1, 1¼ *and* 2 *mm.*

SANGAMO WESTON LTD., ENFIELD, MIDDLESEX

THE JOURNAL
OF
THE ROYAL AERONAUTICAL SOCIETY

With which is Incorporated The Institution of Aeronautical Engineers.

CONTENTS FOR AUGUST, 1944

PAGE

MONTHLY NOTICES 267

AERODYNAMIC FEATURES OF GERMAN AIRCRAFT BY M. B. MORGAN, M.A., A.F.R.Ae.S., and R. SMELT, M.A. 271

REVIEWS 332

THE JOURNAL OF THE ROYAL AERONAUTICAL SOCIETY *was founded in* 1897 *in succession to the* ANNUAL REPORTS.

For the opinions expressed in Papers that are signed or initialled the authors alone are responsible. None of the papers or paragraphs must be taken as expressing the opinion of the Council of the Royal Aeronautical Society unless such is definitely stated to be the case.

The Journal is published monthly at the Offices of the Society, 4, Hamilton Place, Piccadilly, London, W.1.

Subscriptions per annum, £3 . 3 . 0 post free; Single Numbers 5/- or 5/3 post free.

All communications for publication in the Journal, or on general matters affecting the Society, should be addressed to—

The Secretary and Editor,
J. Laurence Pritchard,
4, Hamilton Place, W.1.

The Society's Bankers are Messrs. Coutts & Co.

All communications respecting Advertisement matters should be addressed to—
The Advertisement Manager, Journal of the Royal Aeronautical Society,
4, Hamilton Place, W.1.

Telephone: Grosvenor 3515-3516-3517. Telegraphic Address: "Didaskolos, Audley, London."
Or to— T. G. Scott & Son, Ltd., Talbot House, Arundel House, London, W.C.2.
Telephone: Temple Bar 1942/3.

YES
Telephones—Armley
39234 & 38291 2 lines

Y. E. S. LTD.

YES
Telegraphic Address—
"YES, LEEDS"

PHOSPHOR BRONZE AND GUNMETAL BEARINGS & BUSHES

OF THE HIGHEST QUALITY . . . . CAST BY THE
"EATONIA" (WATER-COOLED) PROCESS

CASTINGS AND BARS AND FINISHED MACHINED PARTS SUPPLIED TO THE LEADING
AEROPLANE ENGINE MAKERS MOTOR VEHICLE ENGINE MANUFACTURERS
MARINE ENGINE BUILDERS

Contractors to all Government Departments

YORKSHIRE ENGINEERING SUPPLIES LIMITED
BRONZE FOUNDRIES, WORTLEY, LEEDS, 12

Aircraft Engineering

FOUNDED 1929

The Monthly Technical and Scientific Organ of the Aeronautical Engineering Profession
Edited by Lt.-Col. W. Lockwood Marsh, O.B.E., F.R.Ae.S., M.S.A.E., F.I.Ae.S.

Single Copies **2s. 3d.** post free. Ordinary Subscription : **26s. 0d.** per annum, post free
SPECIAL SUBSCRIPTION RATE *For Students, Associates and Graduates of the Society* : **21s. 0d.** per annum, post free

PRINCIPAL AUGUST CONTENTS:

Rigidity of Wing and Tail Surfaces. J. L. Beilschmidt.
The Ellipse as Applied to Aircraft. V. B. Billings.
The Design of Struts. R. H. Grundy.
Airscrews as Landing Brakes. A. von der Mühll.
A Report on Enemy Fuel Tanks.
German Pressure-Control Units.

BUNHILL PUBLICATIONS LIMITED, 12 Bloomsbury Square, London, W.C.1

Since 1916

CERTUS COLD GLUE

● *The pro co-operatio our experts Technical is available all time*

Approved to B.S.S. 3.V.2.

has been used extensively throughout the Aircraft Industry in the construction of Air-Screws, laminated Spar Booms for Mainplanes, Centre Sections, etc., wooden Ribs for all Aircraft components and the essential attachment of Plywood skin covering of wooden monocoque Fuselages and other Aircraft components,

CERTUS

Regd. Trade Mark

Phones: HOP 1297 HOP 1558

Sole Manufacturers:

CENTRAL CHEMICALS LIMITED

ADHESIVE SPECIALISTS

CENTRAL BUILDINGS, 24 SOUTHWARK STREET, LONDON, S.E.1

Grams: Entramici Boroh, Lond

(Fully approved for Testing and Issue of Release Notes under Air Ministry Ref. 437610, July, 1923)

A. V. ROE & CO., LIMITED — *Branch of Hawker Siddeley Aircraft Co.,*

FIRTH BROWN

"MITIA"

CARBIDE TIPPED SAWS

Essential to High Speed Production

SPEEDS IN EXCESS OF 3,000 ft. PER MINUTE WITH HIGH RATES OF FEED.

Saws are fitted with renewable inserted teeth

THOS FIRTH & JOHN BROWN LTD — **SHEFFIELD**

THE ROYAL AERONAUTICAL SOCIETY

WITH WHICH IS INCORPORATED THE INSTITUTION OF AERONAUTICAL ENGINEERS.

MONTHLY NOTICES.

AUGUST, 1944.

Associate Fellowship Examinations.

The following candidates were successful in the May, 1944, Associate Fellowship Examinations:—

Ayers, K. B., Strength of Materials (1st Place); Billings, V. R., Design (Aircraft), Aerodynamics, Applied Mathematics (1st Place, tie); Brett, P., Aerodynamics, Theory of Machines (1st Place), Pure Mathematics; Brittain, A. W., Applied Mathematics; Chaplin, N. J., Design (Aircraft), Applied Mathematics; Connolly, T. G., Design (Aircraft); Conway, A., Pure Mathematics; Cosier, P. H., Design (Aircraft), Strength of Materials; Everson, I., Theory of I.C. Engines (1st Place), Strength of Materials, Applied Mathematics (1st Place, tie); Forder, H. P., Strength of Materials, Aircraft Materials (1st Place), Applied Mathematics; Guttridge, J. C., Theory of I.C. Engines, Aerodynamics; Hack, R. E. T., Applied Mathematics; Havard, E. G., Air Transport (1st Place); Hearle, W. G., Pure Mathematics (1st Place, tie); Henley, K. G., Applied Mathematics; Hidson, E. J., Strength of Materials; Jackson, K. T., Aircraft Materials; Jermyn, D. A., Theory of I.C. Engines; Johnson, D., Applied Mathematics; Lee, H. B., Applied Mathematics, Aircraft Instruments; Lloyd, L. M., Applied Mathematics; Magor, G. T., Aerodynamics; Marek, H., Air Transport; McCulloch, J., Aerodynamics; Morrison, M., Strength of Materials, Aerodynamics; Naylor, J. S., Aerodynamics; Prewett, W. C., Aerodynamics; Radford, J., Design (Aircraft), Aerodynamics; Rendle, K. G., Pure Mathematics; Rodgers, T. D., Navigation; Rose, A., Strength of Materials, Pure Mathematics (1st Place, tie), Theory of Machines; Sheikh, G. M., Pure Mathematics; Simpson, E., Theory of I.C. Engines; Skinner, W. A., Aerodynamics, Navigation, Pure Mathematics (1st Place, tie); Taylor, H. S., Applied Mathematics; Thompson, D. I., Theory of Machines; Tooley, C. P. D., Design (Aircraft), Strength of Materials; Wallach, F. J., Design (Aircraft) (1st Place), Aerodynamics (1st Place), Pure Mathematics (1st Place, tie) (Baden-Powell Prize Winner); Wright, D., Strength of Materials, Aerodynamics, Pure Mathematics.

Baden-Powell Memorial Prize.

The Baden-Powell Memorial Prize has been awarded to Mr. F. J. Wallach, who was considered the best student by the Examiners in the May, 1944, Associate Fellowship Examinations.

Graduates' and Students' Section.

A meeting of the Graduates' and Students' Section will be held in the Library, 4, Hamilton Place, W.1, on Wednesday, September 6th, 1944, at 7.30 p.m., when a lecture on "Some Dynamical Problems in Design of Large Aircraft" will be given by Mr. W. S. Hemp, of the Bristol Aeroplane Co.

IMPORTANT NOTICE.

In accordance with a decision taken at the last Annual General Meeting of the Section, the Committee wishes to arrange for each nucleus of members,

whether at firms, establishments or colleges to have its views on the affairs of the Section more adequately represented.

It is hoped to send out to such nuclei a questionnaire on the affairs of the Section, and at a later date to arrange a meeting for a more adequate airing of views.

The Committee would, therefore, be grateful if members of the Section would contact their fellow members at their firm or college and from their number elect one member to correspond with the Secretary of the Section.

When a representative has been chosen, will he please write to the Secretary, giving his own name and address, the name of his firm, or college, and list of the names of the members in the group.

Secretary: E. J. Archbold,
27, North View,
Eastcote, Pinner, Middlesex.

Glasgow Branch.

It has been suggested that a Branch of the Society be formed in Glasgow. Will those members interested write to the following member:—

D. B. R. Briant, A.R.Ae.S.,
23 Thornwood Drive, Glasgow, W.1.

Journals.

The Secretary would very much appreciate it if those members who have finished with their Journals issued in 1944 would return them as the stocks in the Society's possession are very low.

Abstracts from the Scientific and Technical Press and Titles and References of Articles.

The Abstracts and List of References will be issued separately from the Journal in future and sent out with the Journal.

Associate Fellowship Examination, December, 1944.

Entries for the December, 1944, Associate Fellowship Examination must be received by the Secretary by September 30th, 1944.

Elliott Memorial Prize.

The Elliott Memorial Prize has been awarded to A/A Hughes, H. C., who obtained the highest number of marks in the General Studies Examination at Halton.

Election of Members.

The following members were recently elected:—

Associate Fellows.—Eric Watt Bonar, Frank Edward Buckell (from Associate), John Roy Ewans (from Student), Szczepan Grzeszczyk, Arthur Alexander Dashwood Lang, Wyndham Benbow Lewis, Reginald Lovegrove, George Dormer Finlayson Mathers, Stefan Neumark, Douglas Rudolf Pobjoy, David Harry Robbins (from Student), Tadeusz Rudenski, Deryck Charles Smith (from Graduate), Frank Taylor (from Graduate), Stanislaus Edward Wells.

Associates.—Ernest Jeffrey Baker, George Beech, Stanley Gordon Betty, Neill Gibson Bennett, Herbert Leslie Hulme Chadwick, Stanley Dunbar Clayton, Leslie William Cotter, Wilfred Dolman, Hubert Kelsey Gordon-Burge, Reginald Cocking Globe, Archibald John Ferguson, Charles Bernard Harrison, Arthur Stewart Hawkins, Joseph Hood, Arthur Vernon Johnson, Jack Kirby, Reginald Charles Read, Leonard Herbert Roots, Ernest Rowbotham, Graham Aldridge Smith, Gerald Sydney Stone, Gerard de Courcy Meade Taylor, Ernest Edward Trett, Robert Wilson.

Graduates.—Ralph Hawarden Anderson (from Student), Peter Vince Brown (from Student), John Philip Golding (from Student), John Gordon Roxburgh (from Student), Basil Alexander James Scoles.

Students.—Thurstan Haddon Banister, John Alfred Barlow, Alexander Ronald Barrack, John Coates Eggleton, William Gray Foster, Colin Gordon Hamilton, Noel Harry Hooke, Alan MacDonald, John Dennis Heddle Nash, Neville Philip Shevloff, Roy Starmer, John Gordon Swales, Anatol Fels Tein, James Herbert William Wheatley, George Drummond Wilson.

Companion.—Thomas Geoffrey Daish.

Additions to the Library.

The following books have been added to the Library:—

Pamphlets in italics with location reference following in brackets.
Books marked * may not be taken out on loan.

A.a.302.—Aeroplane Flight. H. F. Browne. Longmans Green. 1944. 7/6.

A.a.303.—Mechanics of Flight. A. C. Kermode. Sir Isaac Pitman. 1942. 7/6.

A.a.304/05.—Mechanische Grundlagen des Flugzeugbaues (Vols. 1 and 2). Prof. A. Baumann. Oldenbourg, Berlin. 1913.

B.a.316.—*Hawker "Typhoon" Single-Seater Fighter. Article in "Engineering,"* 28/1/44. (Y.3.ii.H.)

B.a.317.—*The Development of "Mosquito" Aircraft. Article in "Engineering,"* 12/5/44. (Y.3.ii.D.)

B.a.318.—*Aeroplane B.E.2C: Rigging Instructions. Air Ministry Official Publication. (Photostat.)* ca. 1918. (Y.3.i.B.)

B.a.319.—*Avro Biplane, 80 h.p. Air Ministry Official Publication. (Photostat.)* ca. 1918. (Y.3.i.A.)

B.a.320.—*The Wright Flyer. (Catalogue.) Wright Co., Dayton.* ca. 1911. (Y.3.i.W.)

B.a.321.—*Curtiss-Wright Airplane Production. Curtiss-Wright Corporation. (Press Release,* 26/5/44.) (Y.3.ii.C.)

B.a.222.—*Spitfire P.R. Mark XI. Ministry of Aircraft Production. (Press Release,* 13/7/44.) (Y.3.iii.29.)

B.g.138/39.—Taschenbuch der Luftflotten. Ed. by F. Rasch and W. Hormel. Lehmann, Munich. 1914 and 1915 Editions.

BB.b.109.—*The Long Distance Cargo Aircraft. Prof. G. A. Mokrzycki. (Reprint from Quarterly Bulletin of Polish Inst. of Arts and Sciences in America, Jan.,* 1944.) (PBB.1.b.6.)

BB.c.88.—*Note on Curtiss Electric Propeller. Curtiss-Wright Corporation. (Press Release,* 20/3/44.) (Y.7.a.15.)

BB.e.32.—*Keeping America First in the Air. (History and Description of N.A.C.A.) National Advisory Committee for Aeronautics, U.S.A. (Press Release,* 21/3/44.) (Y.11.iv.a.27.)

*D.a.A.24.—*Suggested Revisions of Part 20 of Civil Air Regulations. Civil Aeronautics Board, U.S.A.* (Y.6.ii.c.5.)

*D.a.C.19.—*Civil Aviation (Canada): Summary of Monthly Reports,* 1943. *Dominion Bureau of Statistics, Ottawa.* (File Case.)

D.b.211.—*Aviation and World Security. H. E. Wimperis. (Article in "The Engineer,"* 10/3/44.) (Y.6.ii.b.28.)

D.b.212.—Plan for Post-war Transport. Sir A. Griffith Bowcawen. Modern Transport. 1944. 1/6.

D.b.213.—*The Geography of Post-War Air Routes. (Discussion.) The Royal Geographical Society,* 1944. (PD.1/26.)

D.b.214.—*Wings over the World. (Advance Copy.) "Indicator." W. H. Allen & Co.,* 1944. 6*d.* (PD.1/27.)

*D.b.215.—*Initial Study of Air Transportation. Association of American Rail-Roads. (Air Transport Sub-Committee.)* 1944. (Y.6.a.39.)

D.c.94.—*The Airport and Your Community. Chas. I. Stanton. Civil Aeronautics Board, U.S.A.*, 1944. (Y.4.ii.a.33.)

*D.f.43.—*B.A.I.C. Bulletins, Nos. 2, 3 and 4. British Aviation Insurance Co., Canada.* 1944. (File Case.)

E.h.5.—Die Casting for Engineers. New Jersey Zinc Co., U.S.A. 1942. $1.

EE.b.79.—*Note on Wright Aircraft Engine Production. Wright Aeronautical Corporation, U.S.A. (Press Release, 16/3/44.)* (Y.7.a.16.)

EE.j.40.—*The Development of Wrought Light Alloy Pistons for Aero Engines. (Reprint from "The Automobile Engineer," Feb., 1944.)* (PEE.3.c.9.)

G.a.68.—*Magnesium Foundry Technique. Ian Ross. Magnesium Castings & Products, Ltd. (Reprint from "Foundry Trade Journal," Feb. 3 and 10, 1944.)* (PG.1/24.)

G.c.25.—*Damping Capacity at Low Stresses in Light Alloys and Carbon Steel, with some examples of Non-Destructive Testing. Dr. L. Frommer and A. Murray. (Reprint from "-Journal of the Institute of Metals," Vol. 70, Part 1, 1944.)* (PG.1/23.)

G.e.A.95.—*Machining of Wrought Aluminium Alloys. Wrought Light Alloys Development Association. Information Bulletin No. 7.* 1944. 1/-. (File Case.)

G.e.A.96.—*Some Effects of Temperature on a High Strength Aluminium Alloy (Hiduminium R.R.59). High Duty Alloys, Ltd., 1944. (Reprint from "Metal Treatment," Autumn, 1943.)* (PG.3.a.16.)

I.a.36.—*The Teaching of Mathematics to Physicists. Institute of Physics,* 1944. (PI.1/12.)

M.b.51.—Militär-Funkentelegraphie (German Official Publication). Mittler & Sohn, Berlin. 1915.

N.a.81.—*Problems of Scientific and Industrial Research. Nuffield College. Oxford University Press,* 1944. 2/-. (PN.1.a.10.)

N.a.82.—*Science in the Universities. Association of Scientific Workers. Oxonian Press, Oxford.* 1944. 1/-. (PN.1.a.11.)

R.c.274.—Maschinenflug. J. Hofman. Oldenbourg, Berlin. 1911.

R.c.275.—Die Luftschiffahrt. R. Nimführ. B. G. Teubner, Leipzig. 1910.

*R.f.95.—Aviazione, Idroaviazione. Alessandro Guidoni. Casa Editrice Pinciana, Rome. 1935.

S.b.135.—The R.A.F. in the World War. Vol. 2 (1940-41). Capt. Norman Macmillan. G. G. Harrap. 1944. 12/6.

S.c.13.—Germany's Air Force. O. Lehmann-Russbueldt. G. Allen & Unwin. 1935.

S.c.14.—*Ausbildungsplan der Werftschule Flieger-Ersatz-Abteilung 8, Graudenz. Druckerei "Der Gesellige," Graudenz.* ca. 1915. (Ps.1./15a.)

S.d.88.—Air Power and the Expanding Community. Major Oliver Stewart. George Newnes, Ltd. 1944. 15/-.

*UG.12/4.—Jahrbuch der Lilienthal-Gesellschaft. 1936.

J. Laurence Pritchard, *Secretary and Editor.*

PROCEEDINGS.

A meeting of the Royal Aeronautical Society was held in the lecture hall of the Institution of Mechanical Engineers at Storey's Gate, St. James's Park, Westminster, London, S.W.1, on Thursday, March 9th, 1944, at which Mr. M. B. Morgan and Mr. R. Smelt, of the Royal Aircraft Establishment, Farnborough, lectured on "The Aerodynamic Features of German Aircraft."

In the Chair: Mr. A. Gouge (President of the Society).

The Chairman offered a hearty welcome to Mr. Morgan and Mr. Smelt, neither of whom needed to be introduced to such a meeting. They were both engaged on important work at Farnborough, and they had done much intensive work along the lines they would discuss in their lecture. They would give the meeting the latest information which the enemy could supply.

The President also offered a warm welcome to members of the American Mission who were present, and, in particular, to Mr. T. P. Wright.

AERODYNAMIC FEATURES OF GERMAN AIRCRAFT.

By M. B. Morgan, M.A., A.F.R.Ae.S., and R. Smelt, M.A.

1. Introduction.

Part I. Handling Characteristics.

2. Me. 109E. 3. Me. 110. 4. F.W. 190. 5. Heinkel III. 6. Ju. 88.

Part II. Engine Cooling.

7. General. 8. Liquid cooled engines. 9. B.M.W. 801 engine.

Part III. View.

10. General. 11. Examples of view from German aircraft.

Part IV.

12. Brief discussion.

1. Introduction.

On frequent occasions during the war German aircraft literally fall upon us, and subsequently arrive at our experimental establishments in various stages of disrepair. Usually they are very much the worse for wear, but sometimes good fortune provides specimens in complete working order, or suffering from only minor damage. Factors in securing a good flow of enemy machines are firstly our fighter and A.A. defences; purely from the scientific viewpoint, however, these are not over popular since they tend to inflict rather drastic damage on the specimen; and, secondly, bad navigation, petrol shortage and engine failure.

Among the German types flight tested at our experimental stations have been the Me. 109, Me. 110, F.W. 190, Heinkel 111 and Ju. 88. The lecture will be confined to the aerodynamic features of these types, since it was thought preferable to deal with some of the German aircraft of which the authors have personal knowledge, rather than to attempt a broad survey of the whole field.

It will be appreciated that, while the main interest of a talk on German machines should lie in comparing their good and bad points with those of our own aircraft, such a comparison cannot be made in an open lecture for security reasons.

Information already released dealing with performance tests on enemy aircraft has already appeared in full in the technical press. There is thus no need to

repeat it here. Handling characteristics will first be dealt with, followed by a survey of the aerodynamic features of various engine cooling arrangements devised by the enemy. Finally, although not strictly within the terms of reference, view will be briefly touched upon.

In the handling section (Part I) the old convention of defining control area as total area (including balance), and percentage balance as area ahead of hinge/total area, has been retained. Unless otherwise stated, speeds quoted are pilot's A.S.I. reading.

PART I.

Handling Characteristics.

2. Me. 109E.

2.1 *Brief history.*

The handling qualities of the Me. 109E are of considerable historical interest, since this type formed the backbone of German fighter strength during the Battle of Britain, its opposite numbers on our side being the Spitfire I and Hurricane I. It has thus been thought worth while to deal with its characteristics rather more fully than those of the other German machines considered.

An early version of the Me. 109, flying in 1938, had a 670 B.H.P. Jumo 210 engine, fixed pitch wooden airscrew, and two nose machine guns firing through the airscrew disc. The second stage in its development was the fitting of a twin bladed variable pitch airscrew, and the addition of two wing machine guns. Stage three was the installation of a far more powerful engine, the 1,100 B.H.P. direct injection DB 601, driving a three blade variable pitch airscrew. The wing structure was stiffened up and about 60 lb. of permanent ballast was inserted in the rear fuselage to get the centre of gravity back. This version was known as the Me. 109E. Two machine guns were retained in the fuselage; the wing armament consisted alternatively of two machine guns or two 20 m.m. cannon.

An intact Me. 109E with wing cannon was captured by the French in the summer of 1940, and flown to this country for flight testing.

2.2 *Description.*

2.2.1 *General.* The aeroplane is a low wing monoplane of fairly clean design. A list of aerodynamic data will be found in Table 2.1, a three view general arrangement drawing is given in Fig. 2.1, while photographs of the machine are reproduced in Fig. 2.2.

TABLE 2.1.

Aerodynamic Data.

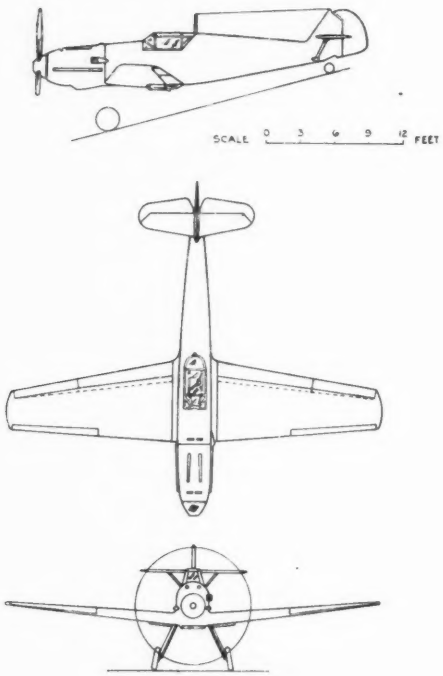
Messerschmitt Me. 109.

General.	
Mean Weight, lb.	5580
S (Gross Wing Area), sq. ft.	174
Engine	*DB* 601
Rated H.P. at 2,400 r.p.m. at 3.75 lb./sq. in. boost pressure at 15,000 ft.	1100
Power Loading (lb./B.H.P.)	5.07
Wing Loading (lb./sq. ft.)	32.1
Span Loading (lb./sq. ft.)	5.32
C.G. *h* (Mean chord = *S*/span)	0.302
Airscrew diameter, ft.	10.2
Gear Ratio	14/9
Wings.	
Area (Gross), *S* sq. ft.	174
Span 2*s* ft.	32.4
Mean chord, *c* ft.	5.36
Aspect Ratio	6.05

Dihedral deg.	5·75
Sweepback of $\frac{1}{4}$ c line	1°
Chord ... { Root. Ft.	7·03
Chord ... { Tip Ft.	3·42
Section ... { t/c Root	0.148
Section ... { t/c Tip	0.105
Slots.	
Slot Length/Wing Span	0.462
Slot chord/Local chord	0.118
Flaps.	
Type.	Slotted
Maximum Angle deg.	42.6
Flap Area/s	0.1425
Flap chord/Local chord	0.246
Flap span/$2s$	0.518
Longitudinal Control.	
Tail surface area (Total) S sq. ft.	24.46
Elevator area/S'	0.371
$l'c$ (l'=distance C.G. to $\frac{1}{3}$ T.P. chord)	3·23
S'/S	0.140
Tail volume coeff. $k=S'l'/Sc$	0.454
Elevator Angles ... { Down	31.6°
(Max. T.P. O°) ... { Up	31.6°
Type of Balance	Horn
Per cent. Balance	10.35
Stick Gearing, $d\eta/dx.$, deg./in.	5.64
Range of T.P. Movement deg. ... ... { ...	+3·4
	...	−8.4
Directional Control.	
Area (Fin and Rudder) S'' sq. ft.	12.61
Rudder area/S''	0.58
l''/s (l''=distance CG to centroid of S'')	13
Fin and Rudder Vol. coeff. $S''l''/Ss$	0.082
Range of Rudder Angle	±33.8°
Type of Balance	Horn
Per cent. Balance	8.47
Pedal Gearing $d\zeta/dx.$, deg./in.	5.63
Lateral Control.	
Aileron Area (Total) sq. ft.	11.0
Aileron Area/s	0.0655
Aileron chord/Local chord	0.235
Aileron span/$2s$	0.357
Aileron Angles ... ... { Down	13.6°
(Max. Flaps at O°) ... { Up	25.0°
Stick Gearing, $d\zeta/dx.$, deg./in. ..	Non - Linear
Droop, deg.	1.2
Per cent. Balance	21.6

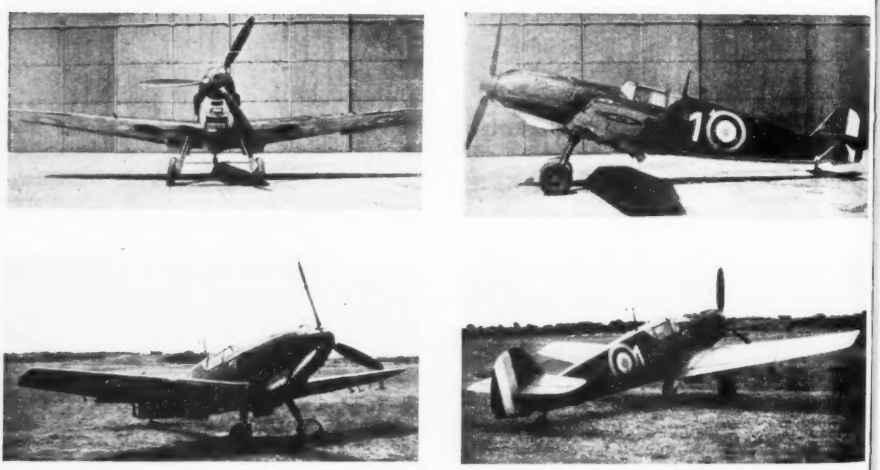
In size the aeroplane is smaller than the Spitfire or Hurricane and by 1940 standards the wing loading is high—about 32 lb./sq. ft., compared with the 25 lb./sq. ft. of the Hurricane I and Spitfire I. The aeroplane is of all metal construction except for the moveable control surfaces and flaps, which are fabric covered. Flush riveting is used throughout.

2.2.2 *Weight and C.G.* During the handling tests the aeroplane was flown at its full service load of 5,580 lb. with the C.G. at 0.3 c; since ballast was added in the correct places in lieu of equipment, the C.G. position should be representative.



MESSERSCHMITT ME 109
(DB 601)

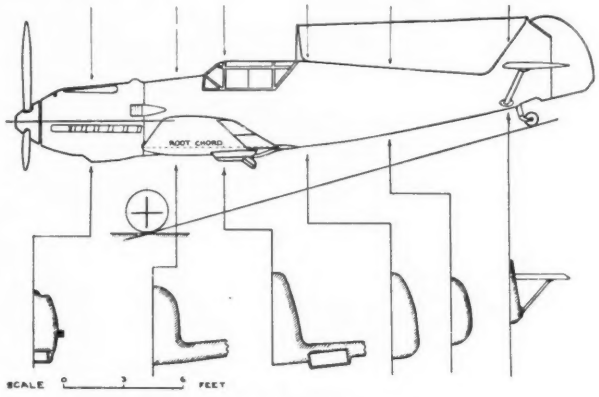
FIG. 2.1.



[Crown copyright reserved.

FIG. 2.2.
Messerschmitt Me. 109.

2.2.3 *Engine and airscrew.* The DB 601 is a direct injection 12 cylinder 60° inverted V glycol cooled engine, of which full descriptions have appeared in the technical press. It drives a 10.2 ft. diameter 3 blade variable pitch airscrew of VDM design. The pilot can set the pitch at any value between 22.5° and 90°, a visual pitch indicator being provided. There is no provision for automatically governing the R.P.M.



ME 109 FUSELAGE SECTIONS.

FIG. 2.3.

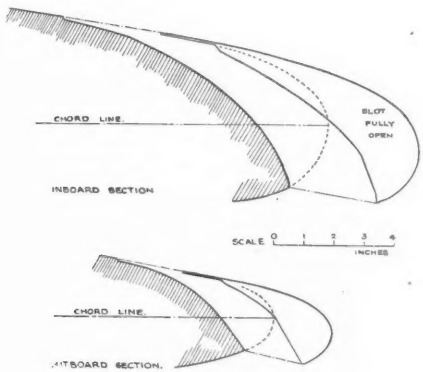


FIG. 2.4.

Me. 109—Slot Sections.

2.2.4 *Wings and fuselage.* A drawing of the fuselage is given in Fig. 2.3. The wings have a straight taper, there is no geometrical twist, and the reaction has 2 per cent. camber with maximum thickness at about 30 per cent. c; thickness cold ratio is 0.148 at the root and 0.105 at the tip.

The automatic leading edge slats are illustrated in Fig. 2.4, and the slotted flaps in Fig. 2.5. No damping device is fitted to the slat mechanism.

2.2.5 *Controls.* Measured stick and rudder pedal gearings are slotted in Fig. 2.6. All three controls are unusually free from friction and backlash. Each control surface is mass balanced, and the stick is statically balanced for fore and aft movement by means of a counterweight in the control circuit.

Drawings of the slotted ailerons are given in Fig. 2.7. As the flaps are lowered the ailerons are automatically drooped, coming down 11° for the full flap movement of $42\frac{1}{2}°$.

The fin and rudder is illustrated in Fig. 2.8, and the tailplane and elevator in Fig. 2.9. The tailplane is high and a large portion of the rudder comes below it, a good anti-spin feature.

No trimmers adjustable in the air are provided on ailerons or rudder, although both controls have small fixed trimmers, which can be bent on the ground. Longitudinal trimming is effected by altering the tailplane incidence, a range of 12° being provided. Both flaps and tail actuating gear are operated mechanic-

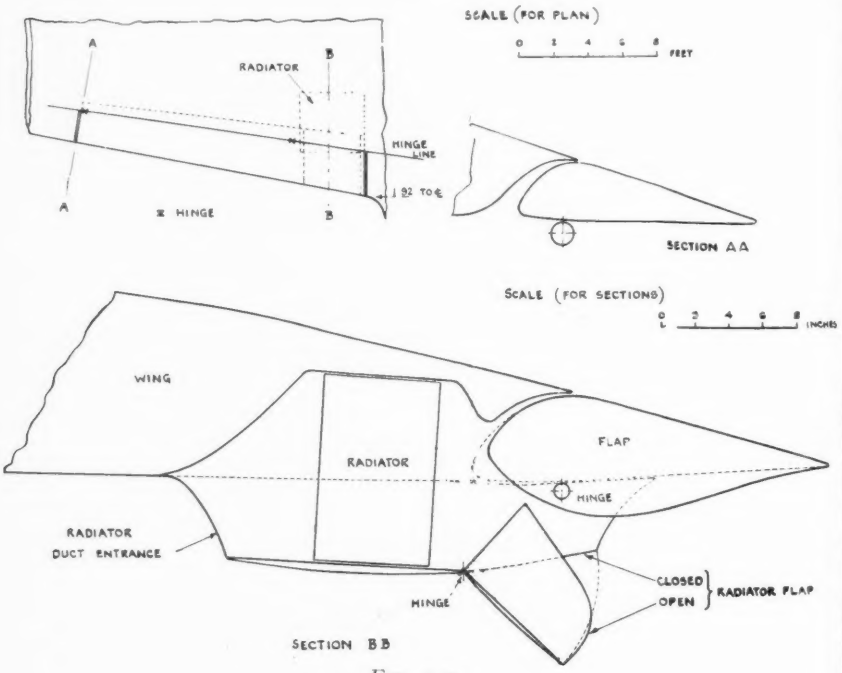


FIG. 2.5.

Me. 109—*Plan and Sections of Flap.*

ally frow two wheels of the same diameter mounted concentrically on the pilot's left. By winding both wheels together with one hand the pilot can thus automatically compensate the change of trim due to flaps.

2.2.6 *Pitot static head.* The position of the pitot static head under the port wing is indicated in Fig. 2.10, together with the position error curve used for interpreting pilot's A.S.I. readings in terms of C_L.

2.2.7 *Performance.* Top speed is about 350 m.p.h. at 18,000 ft. Rate of climb is 2,750 ft./min. at 5,000 ft. and 1,800 ft./min. at 20,000 ft. Service (100 ft./min.), ceiling is roughly 36,000 ft.

2.3 *Take-off and landing.*

2.3.1 *Take-off.* This is best done with the flaps at 20°. The throttle can be opened very quickly without fear of choking the engine. Acceleration is good, and there is little tendency to swing or bucket.

The stick must be held hard forward to get the tail up. It is advisable to let the aeroplane fly itself off, since if pulled off too soon the left wing will not lift, and on applying the aileron the wing lifts and falls again, with the ailerons snatching a little. If no attempt is made to pull the aeroplane off quickly, the take-off is quite straightforward. Take-off run is short, and the initial climb good.

2.3.2 *Approach.* Stalling speeds on the glide are 75 m.p.h. flaps up and 61 m.p.h. flaps down. Lowering the flaps makes the ailerons feel heavier and slightly less effective, and causes a marked nose-down pitching moment, readily corrected owing to the juxtaposition of trim and flap operating wheels.

If the engine is opened up to simulate a baulked landing with flaps and undercarriage down, the aeroplane becomes tail heavy, but can easily be held with one hand while trim is adjusted.

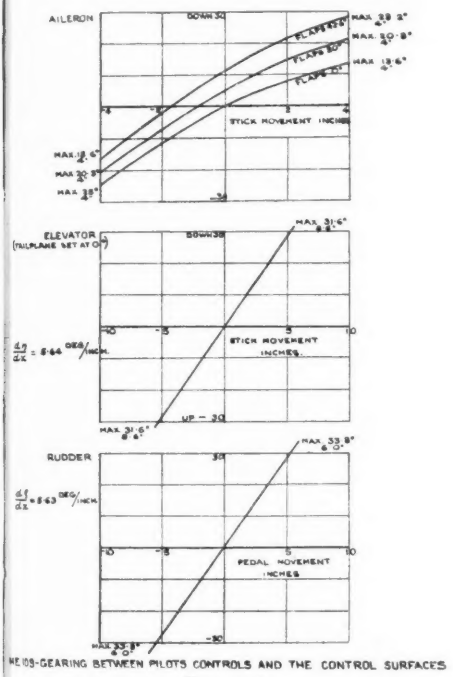


FIG. 2.6.

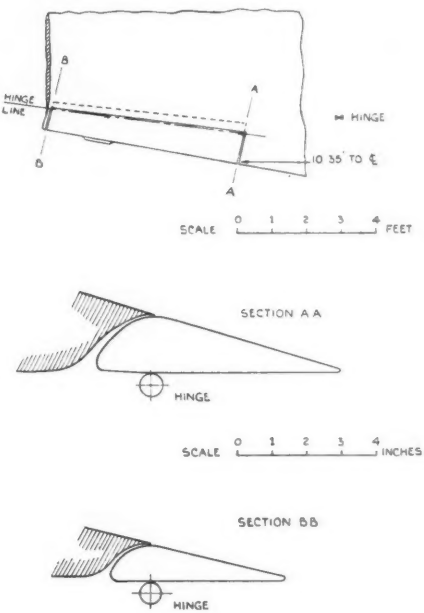


FIG. 2.7.
Aileron—Plan and Sections.

The effect on rate of descent of varying the approach speed, flaps and undercarriage down, is indicated below:—

A.S.I. m.p.h.	V_i m.p.h.	Indicated Rate of descent $V_e\sqrt{\sigma}$ ft./sec.	Gliding angle γ approx.
60	80	26.5	13.0°
70	86	22.5	10.3°
80	93	23.3	9.8°
90	100	24.5	9.6°
100	108	29.2	10.5°

Normal approach speed is 90 m.p.h. At speeds above 100 m.p.h. the pilot has the impression of diving, and below 80 m.p.h. one of sinking.

At 90 m.p.h. the glide path is reasonably steep and the view fairly good. Longitudinally the aeroplane is markedly stable, and the elevator heavier and more responsive than is usual on single seater fighters. These features add considerably to the ease of the approach. Aileron effectiveness is adequate; the rudder is sluggish for small movements.

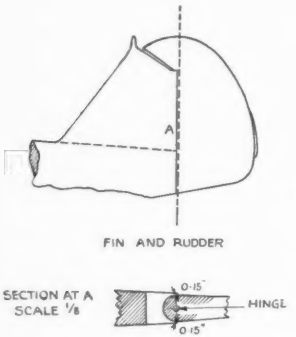


FIG. 2.8.

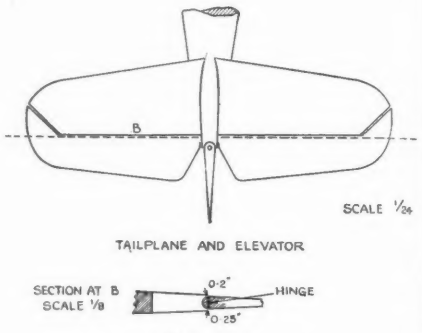


FIG. 2.9.
Messerschmitt Me. 109
Control Surfaces.

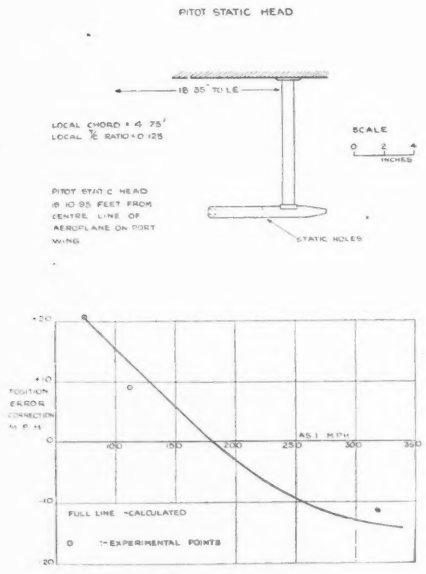
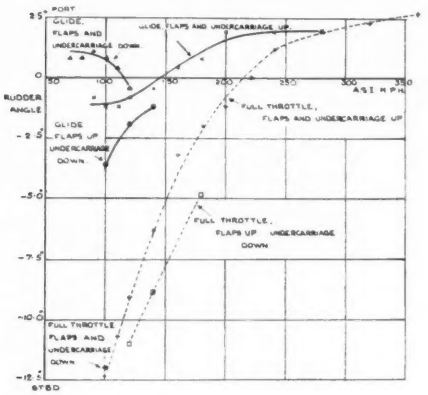


FIG. 2.10.
Me. 109—Position Error
Correction Curve.



RUDDER ANGLES TO TRIM.

FIG. 2.11.

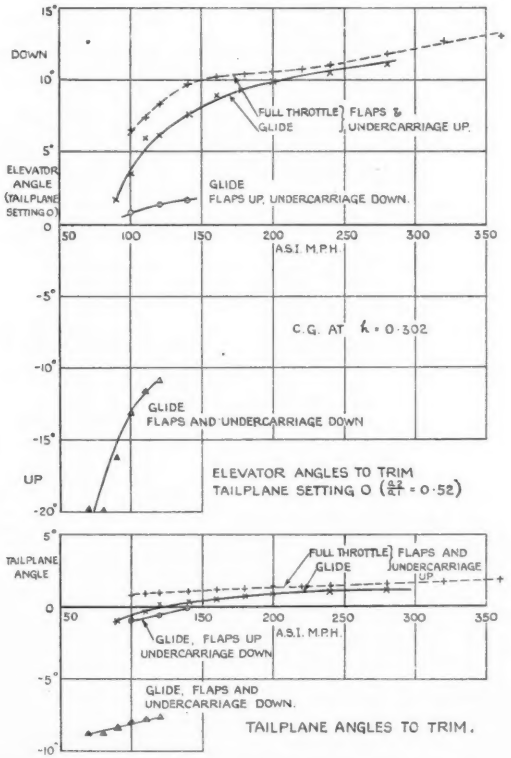

DOWN
UP
ELEVATOR ANGLE (TAILPLANE SETTING 0)
FULL THROTTLE GLIDE FLAPS & UNDERCARRIAGE UP.
GLIDE FLAPS UP, UNDERCARRIAGE DOWN.
A.S.I. M.P.H.
C.G. AT k = 0·302
GLIDE FLAPS AND UNDERCARRIAGE DOWN
ELEVATOR ANGLES TO TRIM TAILPLANE SETTING 0 (dε/dα = 0·52)
TAILPLANE ANGLE
FULL THROTTLE GLIDE FLAPS AND UNDERCARRIAGE UP
GLIDE, FLAPS UP UNDERCARRIAGE DOWN
GLIDE, FLAPS AND UNDERCARRIAGE DOWN.
TAILPLANE ANGLES TO TRIM.

FIG. 2.12.

2.3.3 *Landing.* This is more difficult than on the Hurricane I or Spitfire I. Owing to the high ground attitude, the aeroplane must be rotated through a large angle before touch down, and this requires a fair amount of skill. If a wheel landing is done the left wing tends to drop just before touch-down, and if the ailerons are used to lift it, they snatch, causing over-correction.

The brakes can be applied immediately after touch down without fear of lifting the tail. The ground run is short, with no tendency to swing. View during hold-off and ground run is very poor, and landing at night would not be easy.

2.3.4 *Taxying.* The aircraft can be taxied fast without danger of bucketing, but is difficult to turn quickly; an unusually large amount of throttle is needed, in conjunction with harsh braking, when manœuvring in a confined space. The brakes are foot operated, and pilots expressed a strong preference for the hand operation system to which they are more accustomed.

2.4 *Trim.*

2.4.1. *Lateral.* There is no pronounced change of lateral trrim with speed or throttle setting *provided that care is taken to fly with no sideslip.*

2.4.2 *Directional.* Rudder angles to trim at various speeds when gliding and at full throttle are plotted in Fig. 2.11. Absence of a rudder trimmer is a bad feature, although at low speeds the practical consequences are not so alarming as the curves might suggest, since the rudder is fairly light on the climb. At high speeds, however, the pilot is seriously inconvenienced, as above 300 m.p.h. about $2\frac{1}{2}°$ of port rudder are necessary for flight with no sideslip and a very heavy foot load is needed to keep this on. In consequence, the pilot's left foot becomes tired, and this affects his ability to put on left rudder in order to assist a turn to port. Hence at high speeds the Me. 109E turns far more readily to the right than to the left.

2.4.3 *Longitudinal.* $5\frac{3}{4}$ turns of a 11.7 diameter wheel on the pilot's left are needed to move the adjustable tailplane through its full 12° range. The wheel rotation is in the natural sense.

Tail plane and elevator angles to trim were measured at various speeds in various conditions, with the results given in Fig. 2.12; the elevator angles were corrected to constant tail setting. It will be seen that the aeroplane is statically stable both stick fixed or stick free.

2.5 *" One control " tests, flat turns and sideslips.*

The aeroplane was trimmed to fly straight and level at 230 m.p.h. at 10,000 ft. In this condition the aeroplane is not in trim directionally, a slight pressure being needed on the left rudder pedal to prevent sideslip. This influences the results of the following tests :—

(I) *Ailerons fixed central.* On suddenly applying half rudder the nose swings through about 8° and the aeroplane banks about 5°, with the nose pitching down a little. On releasing the rudder it returns to central, and the aeroplane does a slowly damped oscillation in yaw and roll. The right wing then slowly falls.

Good banked turns can be done in either direction on rudder alone, with little sideslip if the rudder is used gently. Release of the rudder is a steady 30° banked turn in either direction results in the left wing slowly rising.

(II) *Rudder fixed central.* Abrupt displacement of the ailerons gives bank with no appreciable opposite yaw. On releasing the stick it returns smartly to central with no oscillation. If the ailerons are released in a 30° banked turn it is impossible to assess the spiral stability, since whether the wing slowly comes up or goes down depends critically on the precise position of the rudder.

Excellent banked turns can be done in either direction on ailerons alone. There is very little sideslip on entry or recovery, even if the ailerons are used very harshly. In the turn there is no appreciable sideslip.

(III) *Steady flat turn.* Only half rudder was used during this test. Full rudder can be applied with a very heavy foot load, but the nose down pitching moment due to sideslip requires a quite excessive pull on the stick to keep the nose up.

When flat turning steadily with half rudder, wings level, about half opposite aileron is needed. The speed falls from 230 m.p.h. to 175 m.p.h., rate of flat turn is about 110 deg./min.

(IV) *Steady sideslip when gliding.* Gliding at 100 m.p.h. with flaps and undercarriage up the maximum angle of bank in a straight sideslip is about 5°. About $\frac{1}{4}$ opposite aileron is needed in conjunction with full rudder. The aeroplane is fairly nose heavy, vibrates and is a little unsteady. On release of all three controls the wing comes up quickly and the aeroplane glides steadily at the trimmed speed.

With flaps and undercarriage down, gliding at 90 m.p.h., the maximum angle of bank is again 5°, 1/5 opposite aileron being needed with full rudder. The nose-down pitching moment is not so pronounced as before, and vibration is still present. Behaviour on releasing the control is similar to that with flaps up.

2.6 *Stalling tests.*

2.6.1. C_L *max.* The aeroplane was equipped with a 60 ft. trailing static head and a swivelling pitot head. Although, as may be imagined, operation of a trailing static from a single seater with a rather cramped cockpit is a difficult job, the pilot brought back the following results:—

STALLING SPEEDS AND C_L MAX.

$W = 5{,}580$ lb. $S = 174$ sq. f.

Condition.		Pilot's A.S.I.		Indicated airspeed V_i (from trailing static).		C_L	
Flaps and Ailerons	Under-carriage.	Speed at which Slots open. m.p.h.	Stalling Speed. m.p.h.	Speed at which Slots open. m.p.h.	Stalling Speed. m.p.h.	C_L at which Slots open.	C_L max.
Up	Up	111	75	120.5	95.5	0.865	1.4
Down { Flaps 42.5° Ailerons 10°	Up	90	61	100.5	81	1.2	1.9
" "	Down	90	61	100.5	81	1.2	1.9

Lowering the ailerons and flaps thus increases C_L max. by 0.5. This is roughly the value which would be expected from the installation.

2.6.2. *Behaviour at the stall.* The aeroplane was put through the full official tests. The results may be summarised by saying that the stalling behaviour, flaps up and down, is excellent. Both rudder and ailerons are effective right down to the stall, which is very gentle, the wing only falling about 10° and the nose falling with it. There is no tendency to spin. With flaps up the ailerons snatch while the slots are opening, and there is a buffeting on the ailerons as the stall is approached. With flaps down there is no aileron snatch as the slots open, and no pre-stall aileron buffeting. There is thus no warning of the stall, flaps down. From the safety viewpoint this is the sole adverse stalling feature; it is largely offset by the innocuous behaviour at the stall and by the very high degree of fore and aft stability on the approach glide.

2.7 *Flying controls.*

2.7.1 *Safety in the dive.* During a dive at 400 m.p.h. all three controls were in turn displaced slightly and released. No vibration, flutter or snaking developed.

If the elevator is trimmed for level flight at full throttle a large push is needed to hold in the dive, and there is a temptation to trim in. If, in fact, the aeroplane is trimmed into the dive recovery is difficult unless the trimmer is wound back owing to the excessive heaviness of the elevator.

2.7.2 *Ailerons.* At low speeds the aileron control is very good, there being a definite resistance to stick movement, while response is brisk. As speed is increased the ailerons become heavier, but response remains excellent. They are at their best between 150 m.p.h. and 200 m.p.h., one pilot describing them as " an ideal control " over this range. Above 200 m.p.h. they start becoming unpleasantly heavy, and between 300 m.p.h. and 400 m.p.h. are termed " solid " by the test pilots. A pilot exerting all his strength cannot apply more than 1/5 aileron at 400 m.p.h.

Measurements of stick top force when the pilot applied about 1/5 aileron in half a second and then held the ailerons steady, together with the corresponding time to 45° bank, were made at various speeds. The results at 400 m.p.h. are given below:—

Maximum sideways force a pilot can conveniently apply to the Me. 109 stick	40 lb.
Corresponding stick displacement ...	1/5
Time to 45° bank	4 seconds
Deduced balance factor Kb_2	−0.145

Several points of interest emerge from these tests:—

(i) Owing to the cramped Me. 109 cockpit, a pilot can only apply about 40 lb. sideway force on the stick, as against the 60 lb. or more possible if he had more room.

(ii) The designer has also penalised himself by the unusually small stick top travel of ± 4 inches, giving a poor mechanical advantage between pilot and aileron.

(iii) The time to 45° bank of four seconds at 400 m.p.h. which is quite excessive for a fighter, classes the aeroplane immediately as very unmanœuvrable in roll at high speeds.

2.7.3 *Elevator.* This is an exceptionally good control at low airspeeds, being fairly heavy and not over sensitive. Above 250 m.p.h., however, it becomes too heavy for comfort and at 400 m.p.h. is so heavy that manœuvrability is seriously restricted. When diving at 400 m.p.h. a pilot, pulling very hard, cannot put on enough " g " to black himself out; stick force/g probably exceeds 20 lb./g in the dive.

2.7.4 *Rudder.* The rudder is light, but rather sluggish at low speeds. At 200 m.p.h. the sluggishness has disappeared. Between 200 m.p.h. and 300 m.p.h. the rudder is the lightest of all three controls for small movements, but at 300 m.p.h. and above absence of a rudder trimmer is severely felt, the force to prevent sideslip at 400 m.p.h. being excessive.

2.7.5 *Harmony.* The controls are well harmonised between 150 m.p.h. and 250 m.p.h. At lower speeds harmony is spoiled by the sluggishness of the rudder. At higher speeds elevator and ailerons are so heavy that the word " harmony " is inappropriate.

2.7.6 *Acrobatics.* These are not easy. Loops must be started from about 280 m.p.h. when the elevator is unduly heavy; there is a tendency for the slots to open at the top of the loop, resulting in aileron snatching and loss of direction.

At speeds below 250 m.p.h. the aeroplane can be rolled quite quickly, but in the final stages of the roll there is a strong tendency for the nose to fall and the stick must be moved well back to keep the nose up.

Upward rolls are difficult. Owing to elevator heaviness only a gentle pull out from the dive is possible, and considerable speed is lost before the upward roll can be started.

2.8 *Fighting qualities.*

A series of mock dog fights with our own fighters brought out forcibly the good and bad points of the aeroplane. These may be summarised as follows:—

(a) *Good Points.*

(i) High top speed and excellent rate of climb.

(ii) Engine does not cut immediately under negative " g."

(iii) Good control at low speeds.

(iv) Gentle stall, even under " g."

(b) *Bad Points.*

(i) Ailerons and elevator far too heavy at high speeds.

(ii) Owing to high wing loading the aeroplane stalls readily under " g " and has a relatively poor turning circle.

(iii) Absence of a rudder trimmer, curtailing ability to bank left in the dive.

(iv) Aileron snatching occurs as the slots open.

(v) Cockpit too cramped for comfort.

A few of these points may be enlarged upon. At full throttle at 12,000 ft. the minimum radius of steady turn without height loss is about 890 ft. in the case of the Me. 109E, with its wing loading of 32 lb./sq. ft. The corresponding figure for a comparable fighter with a wing loading of 25 lb./sq. ft., such as our Spitfire I or Hurricane I, is about 690 ft. Although the more heavily loaded fighter is thus at a considerable disadvantage, it is important to bear in mind that these minimum radii of turn are obtained by going *as near to the stall as possible.* In this respect the Me. 109E scores by its excellent control near the stall and innocuous behaviour at the stall, giving the pilot confidence to get the last ounce out of his aeroplane's turning performance.

The extremely bad manœuvrability of the Me. 109E at high airspeeds quickly became known to our pilots. On several occasions a Me. 109E was coaxed to self destruction when on the tail of a Hurricane or Spitfire at moderate altitude. Our pilot would do half a roll and a quick pullout from the subsequent steep dive. In the excitement of the moment the Me. 109E pilot would follow, only to find that he had insufficient height for recovery owing to his heavy elevator, and would go straight into the ground without a shot being fired.

Pilots' verbatim impressions of some features are of interest. For example, the DB 601 engine came in for much favourable comment from the viewpoint of response to throttle and insusceptability to sudden negative " g," while the throttle arrangements were described as " marvellously simple, there being just one lever with no gate or over-side to worry about." Surprisingly though, the manual operation of flaps and tail setting were also liked; " they are easy to operate, and, being manual, are not likely to go wrong; juxtaposition of the flap and tail actuating wheels is an excellent feature."

Performance by 1940 standards was good. When put into a full throttle climb at low airspeeds, the aeroplane climbed at a very steep *angle,* and our fighters used to have difficulty in keeping their sights on the enemy even when at such a height that their *rates* of climb were comparable; this steep climb at low airspeed was one of the standard evasive manœuvres used by the German pilots. Another was to push the stick forward abruptly and bunt into a dive with considerable negative " g." The importance ot arranging that the engine should not cut under these circumstances cannot be over-stressed. Speed is picked up quickly in the dive, and if being attacked by an aeroplane of slightly inferior level performance this feature can be used with advantage to get out of range.

There is no doubt that in the autumn of 1940 the Me. 109E, in spite of its faults, was a doughty opponent to set against our own equipment. The design teams responsible for the Hurricane and Spitfire may well be proud of their share in the conclusive outcome of the test.

3. Me. 110.

3.1. *Description.*

Brief handling tests were done on a Me. 110 powered with two D.B. 601A engines. Aerodynamic data is given in Table 3.1, while photographs of the aeroplane will be found in Figs. 3.1, 3.2 and 3.3.

The tail unit is illustrated in Fig. 3.4, the ailerons in Fig. 3.5, slotted flaps in Fig. 3.6 and leading edge slots in Fig. 3.7. The measured stick and pedal gearings are given in Fig. 3.8. Elevator and rudders are fitted with combined balance and trimming tabs; rudder tab gearing 0.4:1, elevator tab gearing 0.8:1.

[*Crown copyright reserved.*]

Fig. 3.1.

[*Crown copyright reserved.*]

Fig. 3.2.

[*Crown copyright reserved.*]

Fig. 3.3.

It will be noted (Fig. 3.6) that the under surface of the flap is bulged immediately behind the radiator, probably, as on the Me. 109, to reduce the exit expansion from the radiator with radiator flap open.

The tail plane setting is automatically altered $-7\frac{1}{2}°$ when the flaps are lowered 50° in order to counteract change of trim. The automatic wing tip slots are very free in action and well fitting when closed.

The aeroplane was flown light at an all-up weight of 13,200 lb. The normal load of the fighter version, at the time of the tests (summer, 1941), was about 13,800 lb. At this load top speed is about 340 m.p.h. at 22,000 ft., rate of climb about 2,200 ft./min. at 5,000 ft. and 1,500 ft./min. at 20,000 ft., while service ceiling (100 ft./min.) is roughly 33,000 ft.

3.2. *Take-off and landing.*

3.21. *Take-off.*

The take-off run seems rather long to the pilot, and rudder has to be used coarsely to prevent swinging in the early stages. Optimum flap setting at the weight tested was 20°. At this setting little effort is required to unstick, whereas with flaps up considerable forward force is needed to get the tail up. The initial climb is excellent, and control is adequate during the climb.

3.22. *Approach and landing.*

The best approach speed, flaps and undercarriage down, is about 95 m.p.h. On lowering the flaps there is a very large change of attitude. At the beginning of the flap movement the nose comes up, and a large forward stick force is needed to counteract this; towards the end of the flap movement the nose sinks, requiring a slight pull to maintain the speed. The eventual change of trim is small. The flaps take about 7 secs. to come fully down at 110 m.p.h.

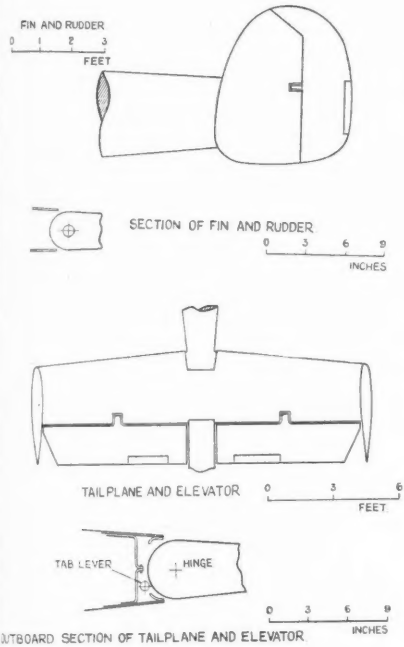


FIG. 3.4.

Messerschmitt 110—*Control Surfaces.*

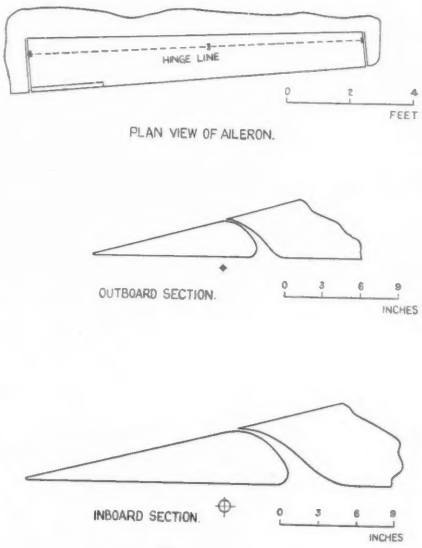


FIG. 3.5.

Messerschmitt 110

Ailerons—Plan View and Sections.

The ailerons (which droop 10° with the flaps) become markedly lighter on putting the flaps down. Rudder and ailerons are unaffected. All three controls are adequate. The longitudinal stability on the glide is exceptionally high. Pilots consider this an excellent feature, since once the aeroplane was trimmed there was little need to watch the A.S.I. closely.

Stalling speed is reduced from 85 m.p.h. to 64 m.p.h. A.S.I. on lowering the flaps. During the approach glide at 95 m.p.h. the slots are about $\frac{1}{4}$ open, and this causes slight aileron buffeting.

View during the approach is excellent, and the landing itself is very straightforward and easy, with none of the tendency for a wing to drop exhibited by the Me. 109E. Heavy braking can be used during the ground run without fear of lifting the tail.

3.23. *Taxying.*

Ground handling qualities are very satisfactory. The aeroplane is easily controlled by use of the engines or of the brakes, which are operated by toe pedals. View while taxying is excellent.

3.3. *Flight on one engine.*

If one engine suddenly cuts when cruising level at 210 m.p.h. the nose swings through about 20° before bank starts to develop, the motion being gentle. Ample trim is available for steady flight on one engine hands and feet off, with the dead engine either feathered or windmilling.

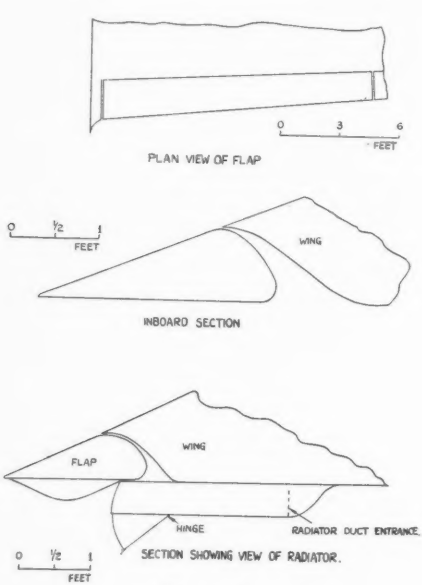


FIG. 3.6.
Messerschmitt 110—*Flap Diagrams.*

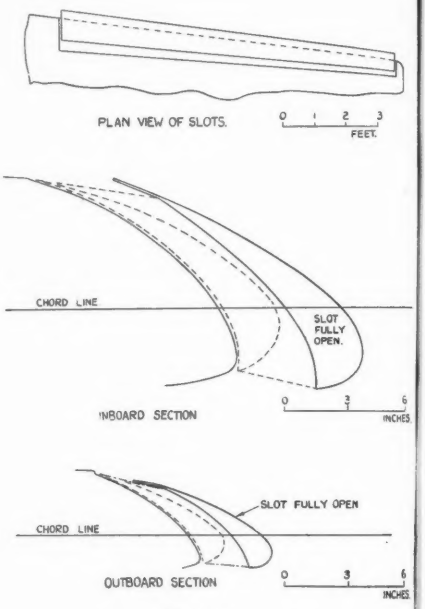


FIG. 3.7.
Messerschmitt 110— *Slots.*

When landing on one engine not more than 20° degrees of flap should be used, otherwise on opening up the good engine to more than 1,600 r.p.m. uncontrollable swing and bank results.

3.4. *" One control tests," flat turns and sideslips.*

The aeroplane was trimmed to fly straight and level at 210 m.p.h.

(i) *Ailerons fixed central.* If 2/3 rudder is quickly applied and then released, the nose swings through about 25° and the appropriate wing falls about 15°. On releasing the rudder it returns to central, the aeroplane does about three oscillations in roll and yaw, and straight and level flight is resumed.

Fairly good turns can be done in either direction, using the rudder alone.

Considerable sideslip occurs during entry and recovery unless the rudder is used very gently, but there is no appreciable sideslip in the steady turn. If the rudder is released in a steady 30° banked turn, bank remains steady.

(ii) *Rudder fixed central.* Abrupt displacement of the ailerons causes little opposite yaw. On releasing the ailerons they return to central.

Excellent banked turns can be done in either direction on ailerons alone with little sideslip.

(iii) *Flat turns.* If much more than $\frac{3}{4}$ rudder is applied the rudder overbalances, possibly due to a stalling of the fin and rudder unit. This is quite marked, the rudder going against its stops, but excessive force is not needed to get it back to central. It would, however, be very unpleasant at higher airspeeds.

Application of $\frac{3}{4}$ rudder, the wings being held level by opposite aileron, gives a rate of flat turn of about 150 deg./min.; roughly $\frac{1}{4}$ opposite aileron is needed. There is a marked nose down pitching moment due to sideslip, needing a fair backward pull on the stick to counteract.

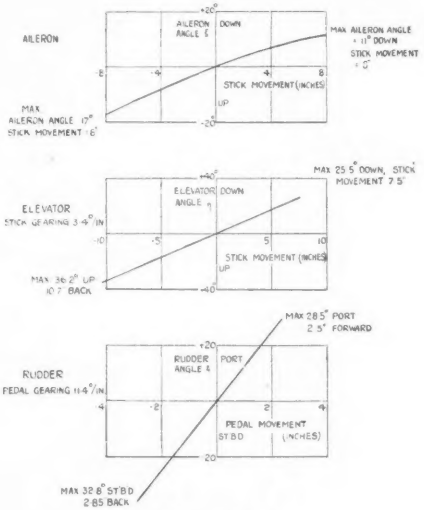


FIG. 3.8.

Messerschmitt 110

Gearing between Pilot's Controls and Control Surfaces.

(iv) *Steady sideslip when gliding.* In a steady sideslip when gliding at 130 m.p.h., flaps and undercarriage up, more than $\frac{3}{4}$ rudder cannot be applied without overbalance. With $\frac{3}{4}$ rudder about $\frac{1}{4}$ opposite aileron is needed to hold the wing down, angle of bank being 35° to port and 20° to starboard. The aeroplane is slightly nose heavy when sideslipping to starboard, but this is not apparent to port. Buffeting of the elevators and rudders accompanies the sideslip. Release of all the controls results in a rapid swing of the nose into the sideslip, the wing stays down, and a steady spiral dive with 45° bank is entered.

With flaps and undercarriage down at 120 m.p.h. behaviour is similar, except that there is pronounced nose heaviness in the sideslip. The rudder

again overbalances at $\frac{3}{4}$ travel, while buffeting of the rudder and elevator is somewhat more pronounced.

3.5. *Behaviour at the stall.*

A straight stall with flaps up or down is very mild. Ample stall warning is given by the aileron vibration accompanying opening of the slots, and at lower speeds by the ineffective " feel " of the ailerons over their central range. A wing drops slowly at the stall, and there is no tendency to spin.

3.6. *Harmony and " feel " of the controls.*

(i) *Ailerons.* At very low speeds (80 m.p.h. flaps down) the ailerons have a poor response over the middle half of their travel, but are effective for larger displacements. As speed is increased to 150 m.p.h. this " dead " region progressively disappears. At 200 m.p.h. response is excellent, but the stick force is rather heavy. This heaviness increases rapidly with speed, and at 400 m.p.h. the ailerons are described as " solid."

The stick force for $\frac{1}{4}$ aileron was measured at various speeds. The pilot applied $\frac{1}{4}$ aileron in about half a second, and held it steady. Time to 45° bank was measured by starting a stopwatch when the ailerons were first moved and stopping it as the aeroplane rolled through 45° bank. The following results were obtained:—

TABLE 4.2.

A.S.I. m.p.h.	Stick force for $\frac{1}{4}$ aileron lb.	Time to 45° bank secs.
200	26.5	1.3
300	27	2.5
350	46.5	2.9
400	46.5	4.0

Judged by fighter standards, the aileron performance of the Me. 110 as indicated by the above figures is extremely bad at high airspeeds.

One other feature may be mentioned. Although when the slots are fully open the ailerons are quite steady, during the opening of the slots, the ailerons snatch. This is a disconcerting feature, particularly in a turn under high "g."

(ii) *Elevator.* At 80 m.p.h. flaps down response is poor for small movements, but adequate for large displacements. The control is heavier than is normal on the approach, but this is quite a good feature. At 150 m.p.h. response is excellent, although the control is on the heavy side. Above 200 m.p.h. the elevator hardens up rapidly, and at high air speeds the elevator forces in a pull-out are quite excessive for a fighter.

(iii) *Rudder.* As with the other two controls, response for small movements at 80 m.p.h. is poor, although after $\frac{1}{2}$ travel it noticeably improves. At 150 m.p.h. response is still poor up to about $\frac{1}{3}$ travel, and the loads are fairly heavy. The dead region disappears at 200 m.p.h. and above, and response is excellent, although the forces build up rapidly with speed. This is not so objectionable on the rudder, however, and small corrections can still be made at 400 m.p.h.

The rudder overbalance in a sideslip after more than $\frac{3}{4}$ rudder has been applied is undesirable at low speeds, and might well lead to accidents at high speeds or when flying on one engine.

(iv) *Harmony.* This is spoiled with flaps down by the extreme lightness of the ailerons. At 200 m.p.h. harmony is good. At higher speeds " feel " is spoilt by excessive heaviness.

(v) *Freedom from friction and backlash.* A very experienced pilot remarked that on the ground the freedom from friction and backlash in all three controls was " extraordinarily good, probably the best met up to now on any twin."

3·7. *Discussion.*

Pilots' impressions were that the Me. 110 is a very pleasant and safe aeroplane for normal flying, but that its handling qualities as a military aircraft leave much to be desired, mainly owing to its lack of manœuvrability at medium and high airspeeds. It may be noted that its wing loading of about 33 lb./sq. ft., which gives a level turning circle of roughly 1,000 ft., would give it an advantage in a slow speed circling dog fight if up against a more heavily loaded twin. Against single engined fighters of about 25 lb./sq. ft. loading, however, it has the advantage neither of turning circle at low airspeeds, nor of manœuvrability at high airspeeds.

TABLE 3.1.

ME. 110 AERODYNAMIC DATA.

General.		
Mean weight (lbs.) during tests		13,220
S (Gross wing area)		415
Engines (Twin Engined Craft)		D.B. 601
Rated H.P. (each)		1,150
Power Loading (lbs./B.H.P.)		5·75
Wing Loading (lbs./sq. ft.)		32·4
Airscrew Diameter (ft.)		10.24
Wings.		
Area (Gross) S (sq. ft.)		415
Span $2s$ (ft.)		53·4
Mean chord c (ft.)		7·78
Aspect ratio		6.86
Dihedral (degrees) (1) to Nacelle		3·75°
(2) Nacelle Out		4. 1°
Sweepback of $\frac{1}{4}c$ line		1.85°
Chord — Root (ft.)		11.05
Chord — Tip (ft.)		4.59
Section — t/c Root		17.6%
Section — t/c Tip		11.5%
Slots.		
Slot length/Wing Span		0.402
Slot chord/local chord		0.14
Flaps.		
Type		Slotted
Mean angle (degrees)		50°
Flap area/S		0.155
Flap chord/Mean chord		0.25
Flap span/$2s$		0.51
Longitudinal Control.		
Tail surface area (total S) (sq. ft.)		69.3
Elevator Areas S'		0.35
$1'\ c$ ($1'$=dist. cg. to 1/3 T.P. Chord)		3.17
Tail Vol. Coeff.		0.167
$S'/S = S'1'/Sc$		0.53
Elevator Angle With T.P.0° — Down		25.5
Elevator Angle With T.P.0° — Up		36.2

Per Cent. Balance	0
Stick gearing $d\eta/dx$ (deg./in.)	3·4
Trimming Tab. Area (sq. ft.) (total)	1.708
Directional Control.	
Area (Fin and Rudder) S'' sq. ft.	32.4
Rudder Area/S''	0.38
$1''/s$ ($1''$=dist. c.g. to centroid of S'')	0.058 (approx.)
Fin and Rudder Vol. Coeff. S'' $1''/Sc$	0.071
Range of rudder angle { In	28.5°
{ Out	35°
Type of balance	Horn
Per cent. Balance	7·4
Pedal gearing $d\zeta/dx$ (deg./inch)	11.4
Lateral Control.	
Aileron Area (Total) (sq. ft.)	29.29
Aileron Areas/S	0.071
Aileron Chord/Local Chord	0.25
Aileron Span/$2s$	0.40
Aileron Angles ... {Down	11°
{Up	17°
Stick gearing $d\zeta/dx$ (deg./inch)	Non-Linear
Per cent. Balance	22%

4. F.W. 190.

4.1 *Description.*

The F.W. 190 is one of Germany's latest fighters. It is a single-seat monoplane of compact design, powered with a B.M.W. 801D 14-cylinder twin-row radial direct injection engine developing about 1,600 h.p. A 10.9 ft. diameter three-bladed V.D.M. airscrew is fitted, provided with hand or automatic pitch control.

Our tests were done on a F.W. 190 A-3. Aerodynamic data is given in Table 4.1, while photographs will be found in Figs. 4.1, 4.2, 4.3 and 4.4. A three-view general arrangement drawing is given in Fig. 4.5.

All-up weight as a fighter is 8,580 lb., giving a wing loading of 41.7 lb./sq. ft. The aerofoil section of the wing is conventional. maximum thickness being at between 25 and 30 per cent. of the chord; average thickness/chord ratio is 12 per cent.

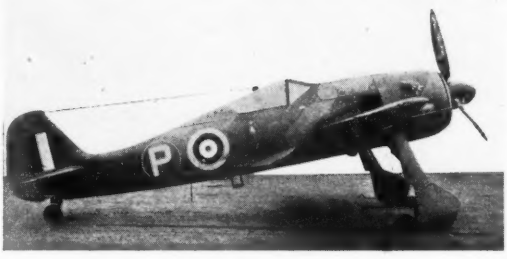
The ailerons are Frise, while elevator and rudder are balanced by shielded horns. No trimmers adjustable in flight are provided for either the ailerons or the rudder. Fore and aft trimming is by means of an adjustable tailplane.

[*Crown copyright reserved.*]

FIG. 4.1.

[*Crown copyright reserved.*]

FIG. 4.2.
F.W. 190. *A*-3.



[*Crown copyright reserved.*]

FIG. 4.3.

[*Crown copyright reserved.*]

FIG. 4.4.
F.W. 190. *A*-3.

Top speed is about 400 m.p.h. at 17,500 ft. The aeroplane can be converted for bombing, carrying a 500 kg. bomb slung under the fuselage; this reduces top speed by roughly 35 m.p.h.; two external long-range jettisonable tanks may also be carried under the wings, these reducing the top speed by a further 40 m.p.h.

The handling tests were done without the bomb and external tanks at an all-up weight of 8,580 lb. with the C.G. in the representative fighter position.

4.2 *General handling.*

Pilot's opinion on the handling qualities are in general very favourable, opinion being unanimous that the aeroplane feels "every inch a fighter." The most

impressive feature is the excellent aileron control at high speeds, and for that reason the ailerons will be discussed in some detail. A few other points emerging from the tests will, however, be first touched upon.

Take-off is fairly straightforward. The change of trim on lowering or raising the flaps is not excessive. Landing is at first rather tricky, since view during the approach is not very good while the approach speed is very high.

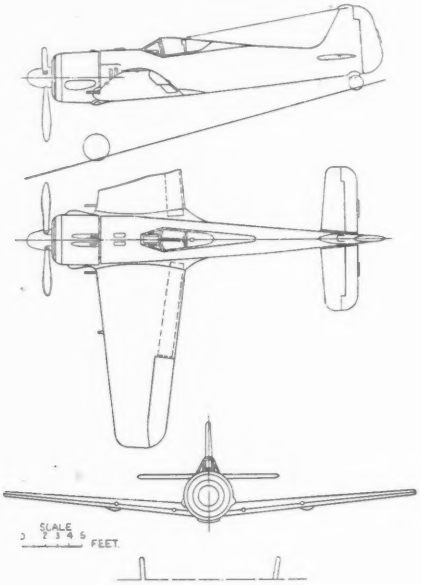


FIG. 4.5.

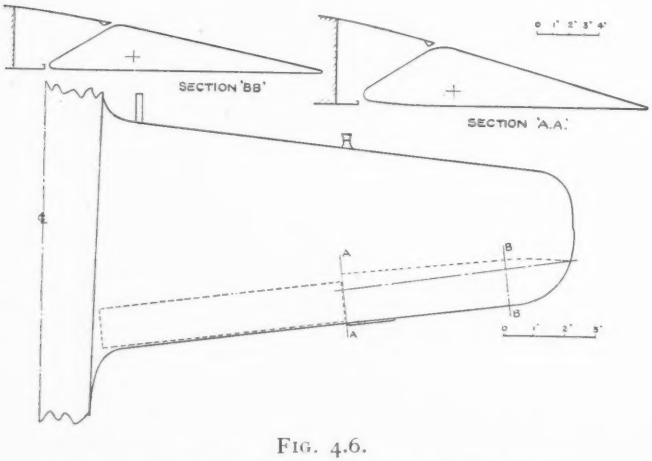


FIG. 4.6.

F.W. 190—Wing Plan Form and Aileron Section.

Longitudinally the aeroplane is just statically stable, stick fixed and free, engine off; and is statically unstable to a slight degree, engine on. The stick force per "g" is a little on the high side, but is not high enough to seriously inconvenience the pilot, being about 9 lb. per "g" up to 300 m.p.h., rising to 12 lb. per "g" at 400 m.p.h. Little use need be made of the fore and aft trimmer when manœuvring, an excellent point.

The absence of a rudder trimmer is not so severely felt as on the Me. 109E, although the out of trim rudder force at high speeds is appreciable. Rudder angles to trim are given in the following table:—

A.S.I. m.p.h.	Glide	Rudder angle for no side-slip Engine on (continuous rating)
150	0°	9½° starboard
200	0°	6° ,,
300	0°	3° ,,
400	0°	2° ,,

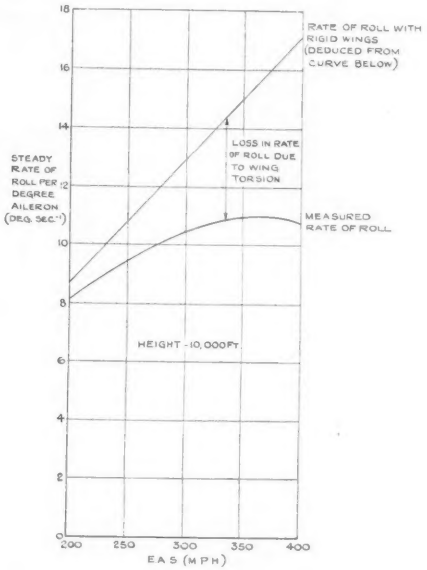


FIG. 4.7.

F.W. 190—Steady Rates of Roll per Unit Aileron Angle.

The results of one control tests show that good turns are possible on ailerons or rudder alone. At 260 m.p.h. more than 1/2 rudder cannot be applied in a flat turn without excessive force, about 1/5 opposite aileron being needed. In straight sideslips at low airspeeds full rudder can be applied, requiring about ¼ opposite aileron to keep the wing down.

With flaps up control is good down to the stall, at which a wing drops. The violence of the wing drop is accentuated in stalls under "g" or with the engine on. If the aeroplane is stalled in a 2 "g" turn to left or right, engine on, the left wing drops violently in each case with little warning, the aeroplane flicking on to its back from a left hand turn.

4.3 *Ailerons.*

Aileron plan form and sections will be found in Fig. 4.6. The ailerons are of Frise type with a fairly sharp nose. They are fabric covered with a close rib spacing—about $4\frac{1}{4}$ in. between adjacent rib centres. Aileron area/wing area is 0.098, percentage balance 28.8 per cent., stick gearing 3.2 deg./inch, maximum aileron angles $\pm 17°$. With aileron central, gap is 0.3 inch at the bottom shroud and 0.25 inches at the top shroud. The ailerons are set with no droop. Operation of the ailerons is via push-pull rods, and ground friction is extremely small.

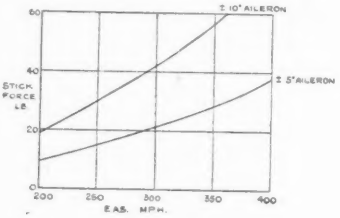


FIG. 4.8.

F.W. 190—Variation of Stick Force with Speed and Aileron Angle.

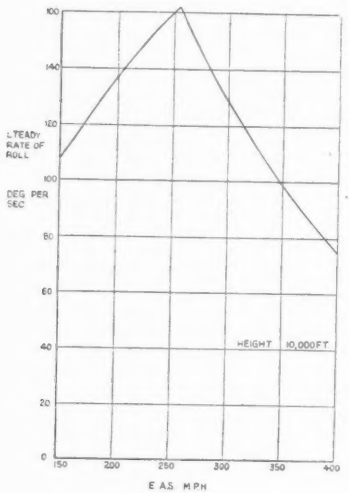


FIG. 4.9.

F.W. 190—Steady Rates of Roll for 50 lb. Stick Force (or full Aileron if this needs less than 50 lb.)

Synchronised automatically recorded readings of aileron angle and angle of bank were taken on a time base at speeds between 200 and 400 m.p.h., when the pilot applied certain definite amounts of aileron and then held the stick steady, rudder fixed central throughout. Stick forces were also measured. All results were corrected to a height of 10,000 ft.

The final steady rate of roll for a given aileron angle was found to be the same to port and starboard, and to be linearly proportional to aileron angle at a given speed. The measured steady rate of roll per unit aileron angle is plotted against airspeed in Fig. 4.7, as is the deduced rate of roll with rigid wings. Assuming the Glauert compressibility correction, it is estimated from these curves that the wing-aileron reversal speed is 760 m.p.h. E.A.S.

The stick force for $\pm 5°$ and $\pm 10°$ aileron is plotted against speed in Fig. 4.8. Overall aileron performance is best illustrated by the curve of Fig. 4.9, in which steady rate of roll generated by a 50 lb. stick force is plotted against speed. Up to about 250 m.p.h. the 50 lb. stick force puts the ailerons on their stops; above 250 m.p.h. more than 50 lb. is needed for full aileron, so the aileron angle decreases progressively with speed. Even so, at 400 m.p.h. the rate of roll is about 75 deg./sec. Peak rate of roll occurs at about 250 m.p.h., being roughly 160 deg./sec.

4.4 *Discussion.*

As a result of light ailerons and elevator, manœuvrability of the F.W. 190 at high airspeeds is excellent. Its high wing loading of over 40 lb./sq. ft., however, inevitably means a poor turning circle at low airspeeds in relation to fighters with loadings of 25-30 lb./sq. ft. Taking this in conjunction with the aeroplane's high top speed and climb, one would expect its pilots to exploit its high speed qualities to the full without staying to " mix it " in a low speed circling dog fight.

Considerable care must be taken in the manufacture of the highly balanced ailerons, since their aerodynamic balance characteristics are bound to be sensitive to small errors in shape arising either from manufacturing errors or from distortion of the fabric under air loads. The close rib spacing, designed to cut down such distortion, is significant. It is known that F.W. 190 ailerons do, in fact, vary considerably in aerodynamic lightness from machine to machine, although the general level is undoubtedly very good; there is no reason for supposing that the aeroplane tested had an abnormally light pair of ailerons compared with the general run of production F.W. 190s.

TABLE 4.1.

F.W. 190 Aerodynamic Data.

General.

Weight during trials	8,580 lb.
S Gross wing area	205.5 sq. ft.
Engine—one	B.M.W. 801.D.
Estimated power (Static 1.35 Atu, 2,450 r.p.m., 14,000′)	1,600 B.H.P.
Power loading	5.36 lb./B.H.P.
Wing loading	41.7 lb./sq. ft.
Span loading	7.21 lb./sq. ft.
Airscrew diameter	10.86 ft.
Gear ratio	

Wings.

Area gross	205.5 sq. ft.
Area nett	179 sq. ft.
Span *2s*	34.5 ft.
Mean chord	5.95 ft.
Aspect ratio	5.8
Dihedral	5°
Sweepback of ¼ chord line	5.5°
Chord root	7.45 ft.
Chord tip	4.05 ft.

Longitudinal Control.	
S' tailplane area gross	31.6 sq. ft.
$1'c$ ($1'$=C.G. to $\frac{1}{4}$ chord T.P.)	0.38 sq. ft.
S/S	2.89
Total elevator area/S'	0.154
Elevator angles { Down	26°
Elevator angles { Up	31°
Type of balance	shielded horn
Percentage balance	9.1%
Stick gearing deg./in.	4.1
Tail volume coefficient	0.445
Directional Control.	
S'' Gross fin and rudder area	24.3 sq. ft.
Rudder area/S''	0.315
$1''/s$ ($1''$=C.G. to centroid of S'')	1.12
Fin and rudder volume coeff. $S''l''/Ss$ ...	0.133
Rudder angles	±16°
Type of balance	shielded horn
Percentage of balance	4.6%
Pedal gearing deg./in.	6
Flaps.	
Type	Split
Maximum angle	60°
Flap area/S	0.091
Flap chord/Local chord) { Inner end ...	0.16
Flap chord/Local chord) { Outer end ...	0.21
Flap span/$2s$	0.55
Central cutaway span/$2s$	0.09
Lateral Control.	
Type	Frise
Aileron area (total)	20.1 sq. ft.
Aileron area/S	0.098
Aileron span/$2s$	0.43
Percentage balance	28.8%
Aileron angles	±17°
Stick gearing deg./in.	3.2

5. Heinkel III.

5.1 *Description.*

The Heinkel III is a somewhat conventional twin-engined bomber, corresponding roughly in size to our Wellington. The model tested was powered with two Jumo 211D engines. The type is old, the original civil He. III being developed in 1935.

Aerodynamic data applicable to the aeroplane tested is listed in Table 5.1, while a three-view general arrangement drawing is given in Fig. 5.1. Drawings of the ailerons are given in Fig. 5.2, of the tailplane in Fig. 5.3, and of the fin and rudder in Fig. 5.4. Slotted flaps are fitted, as illustrated in Fig. 5.5.

Each aileron has two large span tabs, one for trimming and one geared for balance. The rudder and elevator have combined trimming and balance tabs. The tailplane incidence may be adjusted on the ground to three settings, range ±1.6°; this feature may have been introduced to cope with extreme C.G. positions.

A unique feature of the aeroplane is that the pilot is normally totally enclosed in the transparent nose. For take-off and landing he sets going a mechanism which raises both his seat and the main flying controls a foot or so upwards, his head

protruding through a hole in the roof, being shielded from the airstream by a small windscreen which is erected on raising the seat.

5.2 *Take-off and landing.*

5.21 *Take-off.*

This is quite straightforward with no tendency to swing. The initial and final climb are roughly what a pilot would expect from an aircraft of this size and power.

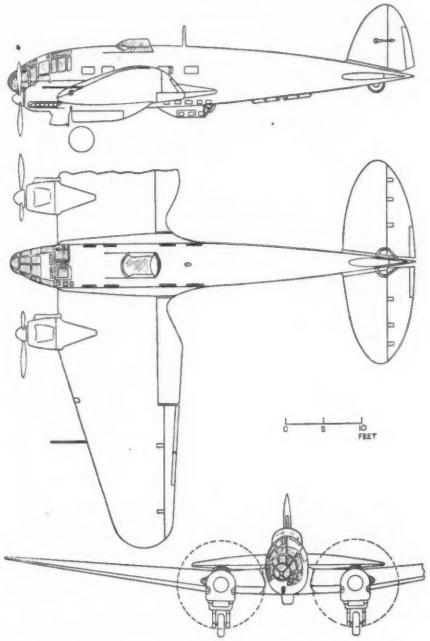


FIG. 5.1.
Heinkel III.

5.22 *Approach and landing.*

The most comfortable approach speed seems to be about 95 m.p.h., there being an impression of sinking at 88 m.p.h. and of diving at 105 m.p.h., flaps and undercarriage down. Stalling speed is 96 m.p.h. flaps up, and 83 m.p.h. flaps down. When gliding at 110 m.p.h. flaps up the aileron control is rather ineffective, and it pays to use engine to assist turns. Lowering the flaps slightly improves the aileron effectiveness. At 95 m.p.h. the flaps come down in 22 seconds, while raising them takes 12 seconds; little change of trim is apparent.

Landing is simple; even an indifferent landing seems good as the aeroplane is difficult to bounce. There is no tendency to swing during the ground run, which is rather long.

5.23 *Taxying.*

The toe brakes are awkward to operate, and heavy pressure is needed on them to get the desired braking effect. As a result, taxying is difficult. View is excellent with the seat in the "up" position.

5·3 *Longitudinal stability.*

Trim curves, done at two C.G. positions, indicate that the aeroplane has an ample static margin, of the order of 0.1c, stick fixed and free, engines off and on; this figure is applicable to the normal C.G. position of about 0.3c.

The elevator trimmer range appears adequate.

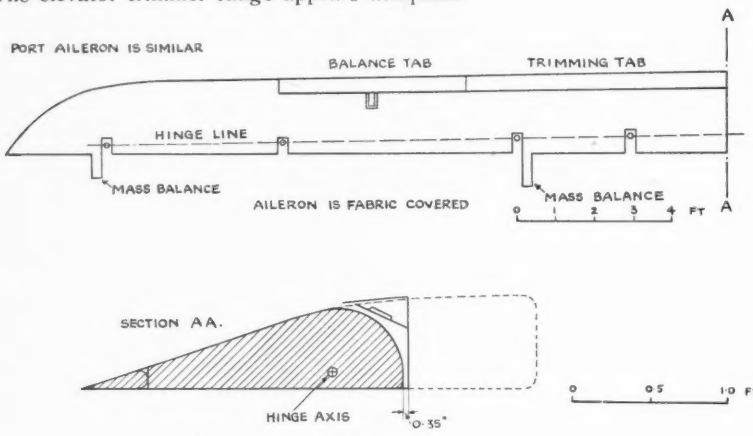


FIG. 5.2.

Heinkel III H—Aileron.

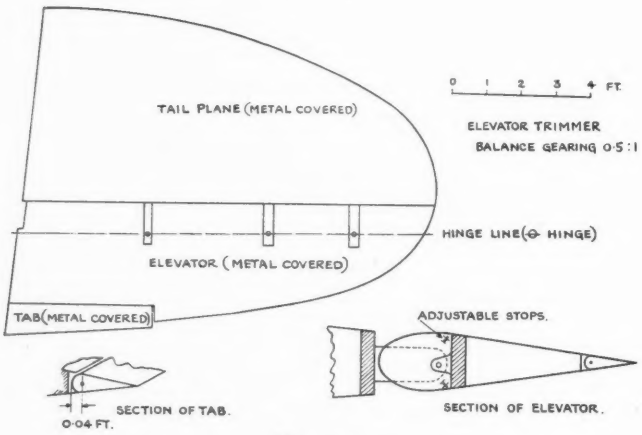


FIG. 5.3.

Heinkel III H—Tailplane and Elevator.

5·4 *Flight on one engine.*

If one engine is throttled back when cruising level at 170 m.p.h. and no corrective action is taken, the aeroplane very slowly goes into a diving spiral with the wing down about 55°. Ample control is available to recover from the spiral without opening up the dead engine.

The aeroplane can be trimmed to fly straight and level on one engine with feet and hands off. It can be flown on one engine with the rudder held central; the

live engined wing must be put down about 12° for this, about half aileron being needed.

5·5 *" One control " tests, flat turns and sideslips.*

The aeroplane was trimmed to fly straight and level at 178 m.p.h.

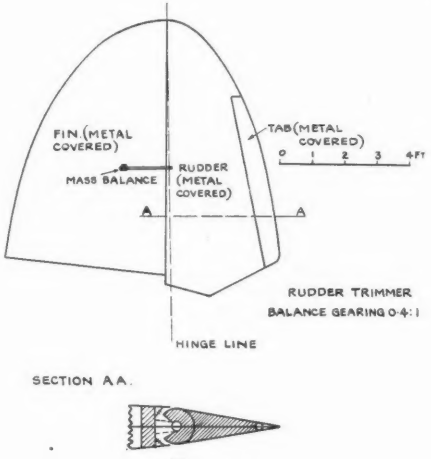


FIG. 5.4.

Heinkel III H—Fin and Rudder.

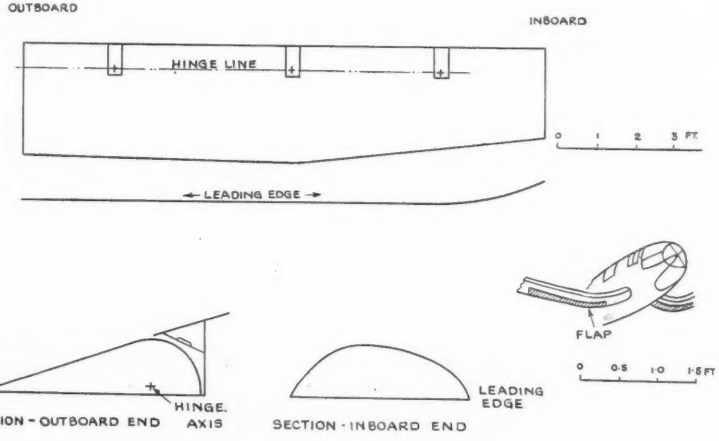


FIG. 5.5.

Heinkel III H—Flaps.

(i) *Ailerons fixed central.*

If the rudder is abruptly displaced the nose swings through about 20° before bank starts to build up. On releasing the rudder it returns to central, the aeroplane does a few oscillations in yaw, and then settles in a banked turn with the wing slowly rising.

Banked turns can be done on rudder alone, ailerons fixed. If the rudder is applied gently, entry and recovery can be made smoothly with little sideslip, while in the steady turn no sideslip is appreciable.

If the rudder is released in a 30° banked turn, ailerons fixed, the wing will eventually slowly come up.

(ii) *Rudder fixed central.*

Abrupt displacement of the ailerons causes appreciable opposite yaw. On release they return to central. Little oscillation of the aircraft is apparent.

Good turns can be made on ailerons alone, hardly any sideslip being noticeable on entry or recovery unless the ailerons are used very harshly.

(iii) *Steady flat turn.*

Full rudder can be applied, but very considerable foot load is needed. There is no tendency for the rudder to overbalance in the sideslip. About half opposite aileron is needed to hold the wing level. Rate of flat turn is very slow.

(iv) *Steady sideslips when gliding.*

The maximum angle of bank in a steady sideslip at 110 m.p.h., flaps and undercarriage up is 20°. Aileron is the limiting control (an unusual feature), about quarter rudder being needed in conjunction with full opposite aileron. The aeroplane becomes slightly tail heavy. On releasing all three controls the aeroplane swings into the sideslip with the nose rising, and the wing comes up.

In a steady sideslip at 110 m.p.h. with the flaps and undercarriage down, aileron is again the limiting control, about half opposite rudder being used with full aileron. The aeroplane is slightly nose heavy in the sideslip, and on releasing the controls the nose drops a little, swings into the sideslip, and the wing comes up.

5.6 *Control " feel."*

The controls are reasonably well harmonised at cruising speed. They become rather heavy in the dive, but show no abnormalities, and " are about correct for this size of aeroplane."

TABLE 5.1

HEINKEL III AERODYNAMIC DATA.

General.	
Mean weight during trials lb.	21,000
Gross weight area (S) sq. ft. . .	918
Engines (2)	Jumo 211D
Rated H.P. at 12,000 ft., 2,400 r.p.m. and 4.7 lb./sq. in. boost pressure B.H.P. ...	1,080
Power loading (lb./B.H.P.)	10
Wing loading (lb./sq. ft.)	23.5
Span loading (lb./ft.)	3.98
C.G. h (mean chord $= S$/span)	0.29
Airscrew diameter ft.	11.46
Airscrew chord at $0.7R$ in.	8.62
Gear ratio	20 : 31
Wings.	
Area (Gross S) sq. ft.	918
Span 2s ft.	73.7
Aspect ratio	5.92
Mean chord c ft.	12.35
Chord { root ft.	15.8
Chord { tip ft.	7.1

Flaps.	
Type	Slotted
Flap area/S	0.041
Flap chord/local chord (mean)	0.21
Flap span/$2s$	0.365
Longitudinal Control.	
Tail surface area/S' sq. ft.	191
Elevator area/S'	0.365
l'/c (l'=distance from C.G. to ½ tailplane chord)	2.82
S'/s	0.208
Tail volume coeff. $S'l'/Sc$	0.585
Elevator angles {down	11.5°
Elevator angles {up	22°
Type of balance	Set back hinge and tab
Percentage balance	29%
Elevator tab angles (max.) {down ...	9°
Elevator tab angles (max.) {up	4°
Tab gearing	0.6
Tab area (total) sq. ft.	3.1
Stick gearing $d\eta/dx$ deg./inch	2.7
Directional Control.	
Fin and rudder area (total) S'' sq. ft. ...	49.5
Rudder area/S''	0.43
l''/s (l''=distance from C.G. to the centroid of S'')	1.00
Fin and rudder volume coeff. $S''l''/Ss$ ...	0.054
Rudder angles	±30°
Type of balance	Tab
Tab gearing	0.6
Tab angles deg.	±12.5°
Tab area (sq. ft.)	2.88
Rudder gearing $d\xi/dx$ deg./in.	9.0
Lateral Control.	
Aileron area (total) sq. ft.	67.2
Aileron area/S	0.073
Aileron chord/local chord (mean)	0.15
Aileron span/wing span	0.505
Aileron angles (max.) {down	22.5°
Aileron angles (max.) {up	22.5°
Trimming tab area sq. ft.	2.72
Percentage balance	19%
Stick gearing $d\xi/dx$ deg./inch	2.5
Trimming tab angles (max.) {down ...	7.5°
Trimming tab angles (max.) {up ...	6°

6. Ju. 88.

6.1 *Description.*

The Ju. 88 is an exceptionally interesting aeroplane. Fairly full descriptions of the various sub-types have already appeared in our technical press from time to time. It is a medium-sized twin-engined aeroplane of versatile role—bomber, dive-bomber and fighter. The "A" series are fitted with Jumo 211 engines; the more recent series have B.M.W. 801 engines. At an early stage in the develop-

ment of the "A" series the wing area was increased from 549 to 583 sq. ft. by increasing the wing span about 6 ft. to 65.6 ft., the ailerons being extended slightly at the same time; this alteration has been kept in all subsequent types, and some of the earlier A1-A4 marks were modified retrospectively.

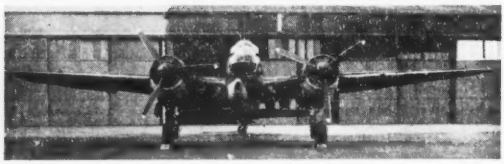
A photograph of the A1 with short span wings is given in Fig. 6.1, while the A6 with larger wings and complete with bombs is illustrated in Fig. 6.2. Aerodynamic data for the A1 is listed in Table 6.1, while a sketch illustrating the plan form of the wings on A1 and A6 is given in Fig. 6.3.

A typical bomb load of the aeroplane, 4,400 lb., gives an all-up weight of about 28,000 lb., wing loading 48 lb./sq. ft. (larger wings). Maximum bomb load is 6,600 lb., all-up weight being then 30,300 lb., wing loading 52 lb./sq. ft. The aeroplane should not be landed at a wing loading much greater than 40 lb./sq. ft., and provision is made for quickly jettisoning the fuel. Attachments are also provided for rocket-assisted take-off.

Top speed is about 290 m.p.h. with no external bombs, and 270 m.p.h. with bombs, the top speeds being obtained at roughly 15,000 ft. Service ceiling at 28,000 lb. is about 24,000 ft. The above figures apply to Jumo 211-J engines.

[*Crown copyright reserved.*]

FIG. 6.1.



[*Crown copyright reserved.*]

FIG. 6.2.

The aeroplane has a number of interesting mechanical devices designed to assist the pilot in his handling of the aeroplane.

(i) The flaps may be lowered to two positions, roughly 25° for take-off and 50° for landing. With flaps up a small movable plate covers the slot gap on the wing under surface, thereby reducing drag. During the first 15° of the flap movement this plate is moved upwards, thereby opening the slot, as illustrated in Fig. 6.4. Aileron section is given in Fig. 6.5.

(ii) On lowering the flaps through their first 25° the ailerons are both drooped about 15° in order to increase C_L max.

(iii) On lowering the flaps fully, the tailplane incidence is automatically decreased by 5° in order to counteract the change of trim and to help in getting the tail down on landing.

(iv) On lowering the dive brakes (Fig. 6.6) the elevator trimming tab is automatically moved up to counteract change of trim.

(v) Pull-out from a steep dive during dive-bombing is automatic, as discussed in §6.74.

(vi) The rudder is fitted with a spring tab to assist in handling the aeroplane on one engine. The tab comes into action when the pilot's foot load exceeds about 30 lb. The same tab is used for trimming.

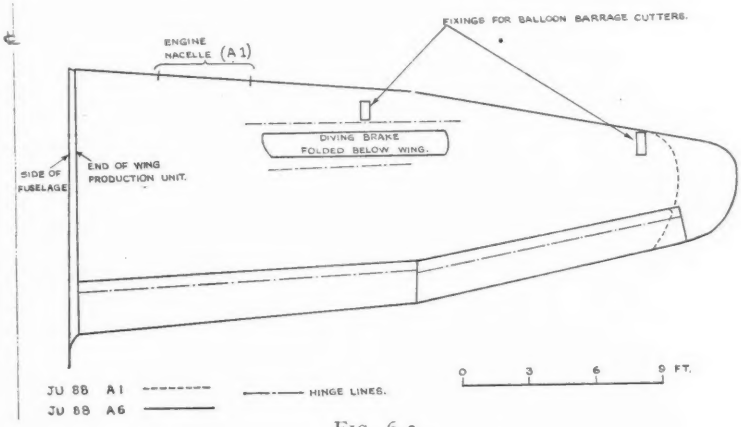


FIG. 6.3.

Wing Plan Forms of Junkers Ju. 88, A1 and A6.

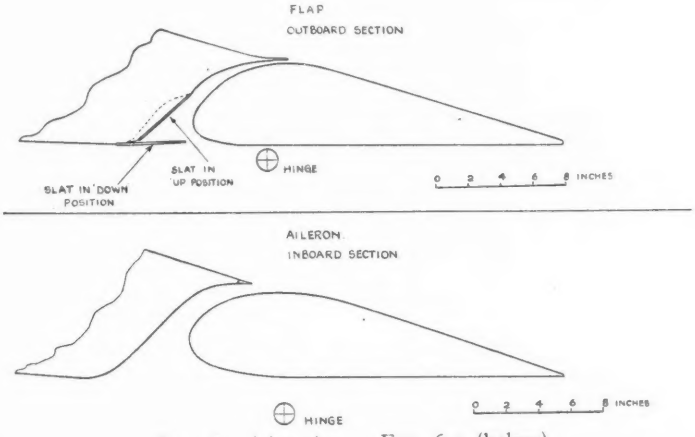


FIG. 6.4 (above). FIG. 6.5 (below).

Flap and Aileron Sections—Ju. 88.

(vii) The aileron forces are reduced at large aileron displacements by swinging weights in the wing tips. A full discussion of this device will be found in the Appendix.

The handling tests to be described were done on a Ju. 88 A-6 with the large span wings, the all-up weight during the tests being about 23,000 lb., i.e., wing loading 40 lb./sq. ft.

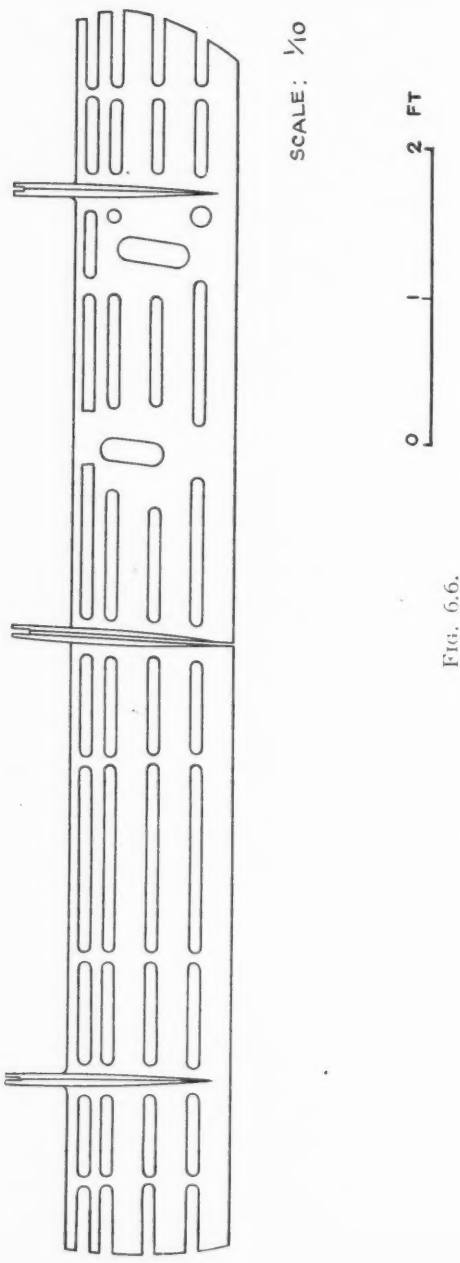


FIG. 6.6.
Junkers Ju. 88—Diving Brake (Starboard Wing).

6.2 *Take-off and landing.*

6.21 *Take-off.*

The aeroplane must be taxied straight just before opening up the throttles in order to lock the tail wheel in the correct fore and aft position. Provided the throttles are opened up slowly and evenly, the tendency to swing is not very marked, while above 50 m.p.h. the rudder becomes very effective. The aeroplane does not readily fly itself off, the control column having to be pulled back firmly to unstick. Take-off run is rather long, but speed builds up rapidly once off the ground, giving full control in a short space of time. The initial rate of climb is moderate. 25° flap was used for the take-off.

6.22 *Approach.*

The undercarriage should be lowered at about 2,000 ft. At the appropriate time the flap lever is moved into the first position from neutral. This half lowers the flaps and droops the ailerons; change of trim is small. During the final stage of the approach the flap lever is brought to the second position. This brings the flaps fully down and decreases the tailplane incidence, necessitating a push on the control column.

A certain amount of engine is normally used during the approach. If the engines are throttled right back the best approach speed is about 115 m.p.h.; at 105 m.p.h. there is a sensation of sinking, and at 125 m.p.h. one of diving. Stalling speed flaps down is 93 m.p.h., and 116 m.p.h. with flaps up. On lowering the flaps control in general feels more "sloppy," but is quite adequate on the glide.

6.23 *Landing.*

The aeroplane is not easy to land. It is very difficult to get the tail fully down, the brakes must be used with caution after a wheel landing, while there is a tendency to swing after touch-down which must be immediately corrected.

6.24 *Baulked Landing.*

The engines can be opened up fully with flaps and undercarriage down, and the aeroplane climbed away without undue difficulty. The undercarriage comes up in about 12 seconds. On raising the flaps, which come up in about 10 seconds, there is a marked sink, the nose drops rapidly and the speed increases quickly. A hard pull on the stick is needed to keep the nose up, and in the interests of safety the flaps should not be raised below about 1,000 ft.

6.25 *Taxying.*

The aeroplane handles well on the ground. Care must be taken to see that the tail wheel is unlocked (as a safety feature, to prevent retraction of the tail wheel when skew, the hydraulics are automatically put out of action unless the tail wheel is locked central). The brakes are particularly effective.

6.3 *Longitudinal stability.*

The centre of gravity limits are from 2.48 to 3.55 ft. aft of the root leading edge; since the aerodynamic chord is 9.18 ft., this gives a C.G. range of about 11½ per cent. of the mean chord. Trim curves at two C.G. positions suggest that even with C.G. aft the aeroplane has a large static margin in hand, stick fixed and stick free, of the order of 0.1c on the glide and slightly less at full throttle.

6.4. *Flight on one engine.*

If one engine is suddenly throttled back when cruising level at 220 m.p.h. and no corrective action is taken, the aeroplane banks fairly sharply and loses height, speed building up rapidly. Recovery is very easy owing to the lightness and effectiveness of the ailerons. The aeroplane can be trimmed to fly straight and level with feet and hands off, about quarter rudder being necessary.

Behaviour on throttling back one engine during a climb at 150 m.p.h. is far more violent, and unless prompt corrective action is taken to prevent the wing

dropping over 1,000 ft. may well be lost. Provided the ailerons and rudder are applied promptly, however, correction is quite easy and there is no necessity to throttle back the live engine to retain control. Enough rudder tab is available to trim when climbing on one engine.

Recovery is rather more difficult if the flaps are set in the take-off position when climbing, as the ailerons are heavier and the manœuvre somewhat more violent. During all these engine cutting tests the virtues of the light spring tab rudder and the light ailerons were very apparent.

Landing with one engine dead is rather precarious, owing to the violent swing and bank accompanying opening up the good engine when correcting the flight path at very low airspeeds.

6.5. *" One control " tests, flat turns and sideslips.*

The aeroplane was trimmed to fly straight and level at 180 m.p.h., 10,000 ft.

(i) *Ailerons fixed central.*

On suddenly applying the rudder swing and bank build up rapidly. The rudder returns to central sharply on release, and after a few oscillations in yaw and roll the aeroplane settles in a banked turn.

Good banked turns can be done on rudder alone, the aeroplane banking unusually quickly in response to rudder movement.

(ii) *Rudder fixed central.*

The ailerons can be applied violently without appreciable opposite yaw. On releasing the stick it oscillates from side to side a few times before returning to central. The aeroplane does a few oscillations in roll before settling down after release of the stick.

Excellent banked turns can be done on ailerons alone, with little sideslip in entry or recovery.

(iii) *Steady flat turns.*

Full rudder can be applied, although considerable force is needed to get it fully on. About $\frac{3}{4}$ opposite aileron is required to hold the wings level. Rate of flat turn is roughly 120 deg./min. There is no pronounced nose-heaviness.

(iv) *Steady sideslips when gliding.*

Gliding at low speeds with flaps and undercarriage up the maximum angle of bank in a straight sideslip is about 30°, obtained with full rudder and $\frac{3}{4}$ opposite aileron. There is little nose-heaviness. Behaviour is the same with flaps and undercarriage down, except that there is slightly more nose-heaviness. In both cases the wing comes up rapidly on releasing all three controls, and the aeroplane quickly settles in a straight glide or a shallow turn.

6.6. *Stalling behaviour.*

Behaviour in a straight stall with the engines throttled back is fairly mild, flaps up or down. With flaps up the control effectiveness decreases progressively as the stall is approached, and at the stall the nose drops abruptly with little tendency for a wing to go down viciously. With flaps down more warning is given, since the loss of control effectiveness is more marked, and a buffeting is felt on the elevator at 96 m.p.h., some 3 m.p.h. before the stall.

6.7. *Flying controls.*

6.71. *Ailerons.*

Aileron control is excellent. Response is adequate at low speeds and for dealing with a sudden engine cut, while at high speeds the stick forces are extremely light. At 300 m.p.h. more than $\frac{3}{4}$ aileron can easily be applied with one hand. At 240 m.p.h. the time between the initiation of the stick movement and the stage at which the aeroplane reached 45° bank in a steady roll was measured, when the pilot applied nearly full aileron vigorously. The surprisingly low figure of 0.7 seconds to 45° bank was recorded. This places the Ju. 88 quite

out of the common run of bombers as regards aileron performance at high speeds. The feature is, of course, of the utmost value in avoiding action.

This lightness of aileron control springs partly from aerodynamic balance and low stick gearing, and partly from an ingenious mechanical device for lightening the ailerons at large displacements. A full description and discussion of this device will be found in Appendix I. Briefly, swinging weights mechanically geared to the ailerons are mounted inside each wing tip in such a manner that when the aeroplane rolls, the centrifugal force on the weights generates a relieving hinge moment proportional to the cube of the aileron angle. Such a device can be arranged to very appreciably relieve the pilot's effort during violent manœuvres.

6.72. *Elevator.*

The elevator control would be inadequate for landing were it not for the automatic coupling of tailplane and flaps which decreases the tailplane incidence 5° on lowering the flaps fully. Even so there is barely sufficient elevator control for getting the tail down on landing with the C.G. forward.

The elevator is pleasantly light and effective at all speeds. At 250 m.p.h. a normal acceleration of 4g can be put on by pulling fairly hard, without assistance from the tabs. Vigorous avoiding action is thus possible.

6.73. *Rudder.*

The rudder is considerably lighter than is usual on aeroplanes of this size, owing to the spring tab mechanism. This is a very good feature from the viewpoint of engine cutting and evasive action. The rudder, although still light, is not oversensitive in the dive.

6.74. *Divebrakes.*

The procedure for dive-bombing with dive brakes out and automatic pull-out is interesting. Before entering the dive a contacting altimeter, which sounds a horn at any selected altitude, is set for the height at which the bombs are to be released; and the bomb distributor is adjusted with the assistance of standardised tables. The elevator trimmer is then set to a fixed mark, which trims the aeroplane nose-heavy, and the dive is started. As the speed builds up, the dive brake lever is operated and the engines throttled back.

Operation of the dive brake lever lowers the dive brakes and at the same time moves the elevator trimming tab up through 2.5°. This moves the elevator down, and causes the aeroplane to drop its nose rapidly. When a pilot first goes through the routine he finds this part of the operation quite alarming, since the aeroplane appears to bunt suddenly, with appreciable negative "g" for a short period.

However, the tab settings are so adjusted that the aeroplane automatically trims itself in a roughly 50° dive, during which the speed builds up to about 310 m.p.h. after a height loss of 6,000 ft. During this period the pilot can judge his dive angle approximately by means of inclined lines painted on one of the transparent cockpit panels. He concentrates on getting his sights on the target in a steady dive at the selected angle.

When the pre-set height is approached the contacting altimeter sets a horn going. On reaching the selected height the horn noise suddenly stops. The pilot immediately presses the bomb release button.

The 2½° up tab movement obtained on lowering the dive brakes compresses a spring in the tab circuit. The spring is tripped, via a solenoid device, on pressing the bomb release button, and the elevator tab is thereby abruptly jerked back 2½° down. This moves the elevator up, and pulls the aeroplane out of the dive with a normal acceleration of about 3½ "g."

During the pull-out, at a pre-selected time after the bomb release button which initiates the pull-out has been pressed, the first bomb is automatically released. The whole purpose of releasing the bomb during the pull-out is, of course, to compensate for the curved trajectory of the falling bomb. The German technicians

have attempted to make the process as definite as possible by reducing the possibility of piloting errors.

The pilot is not restricted to a 50° dive; any angle in the range 30° to 70° may be used. Provision is also made for use of the automatic pull-out device with dive brakes retracted for steep dive-bombing from very low altitudes.

6.8. *Violent evasive action.*

A few brief tests were made as a basis for calculating the probable flight paths of the Ju. 88A-6 if the pilot took various violent evasive actions after releasing his bombs.

The first point to be determined in such action is the time taken to achieve a steady bank of 60° or more by applying aileron quickly and then almost immediately holding it off to keep the bank steady; the second point is the maximum "g" that can conveniently be applied as soon as the bank is on. The following results were obtained at 1,500 ft., all-up weight 22,000 lb.:—

Speed (E.A.S.) m.p.h.	Angle of bank	Time to achieve steady bank, secs.	Steady "g" in the turn	Speed after turn through 360° m.p.h.
250	70°-80°	2.0	3.5	230
200	70°-80°	2.0	2.75	185
150	60°-65°	1.5	2.0	140

The characteristics of violent "zooms" done by pulling the stick back vigorously when flying straight and level were next examined at 1,000 ft., with the following results:—

Speed (E.A.S.) m.p.h.	Maximum "g" in the "zoom."	Time to reach maximum "g" secs.	Time to gain 100 ft. secs.	Speed after given height gain.
250	4	1.5	2.0	230 m.p.h. after 150 ft. gain.
200	3	1.0	2.0	165 m.p.h. after 200 ft. gain.

With the above figures as guidance, step-by-step calculations were done, covering the following ground:—

(i) Flight paths during violent turns at constant height (Fig. 6.7).
(ii) Flight paths during "zooms" (Fig. 6.8).

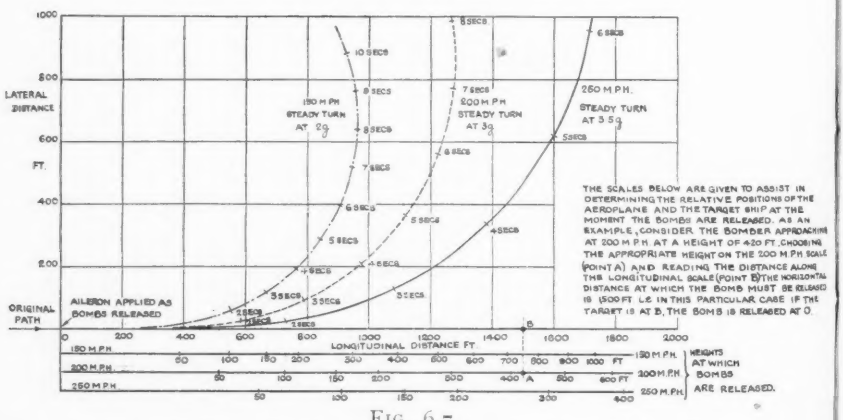

LATERAL DISTANCE FT.
ORIGINAL PATH
AILERON APPLIED AS BOMBS RELEASED
150 M.P.H. STEADY TURN AT 2g
200 M.P.H STEADY TURN AT 3g
250 M.P.H. STEADY TURN AT 3.5g
THE SCALES BELOW ARE GIVEN TO ASSIST IN DETERMINING THE RELATIVE POSITIONS OF THE AEROPLANE AND THE TARGET SHIP AT THE MOMENT THE BOMBS ARE RELEASED. AS AN EXAMPLE, CONSIDER THE BOMBER APPROACHING AT 200 M.P.H. AT A HEIGHT OF 420 FT., CHOOSING THE APPROPRIATE HEIGHT ON THE 200 M.P.H. SCALE (POINT A) AND READING THE DISTANCE ALONG THE LONGITUDINAL SCALE (POINT B) THE HORIZONTAL DISTANCE AT WHICH THE BOMB MUST BE RELEASED IS (500 FT. I.E. IN THIS PARTICULAR CASE IF THE TARGET IS AT B, THE BOMB IS RELEASED AT O.
LONGITUDINAL DISTANCE FT.
150 M.P.H.
200 M.P.H.
250 M.P.H.
HEIGHTS AT WHICH BOMBS ARE RELEASED.

FIG. 6.7.

Ju. 88—Level Turns at 150 m.p.h., 200 m.p.h. and 250 m.p.h.

These calculations were done assuming an all-up weight of 24,000 lb., and give one an idea of the position of the aeroplane after a low-level bombing attack.

Tests were also made to provide the basis for flight path calculations applicable to a dive-bombing attack. The results of the calculations are given in Fig. 6.9, applicable to a weight of 26,200 lb. bombs on, and 24,000 lb. bombs off.

Study of these flight path diagrams brings home vividly the varied problems of anti-aircraft gunnery against low-flying machines.

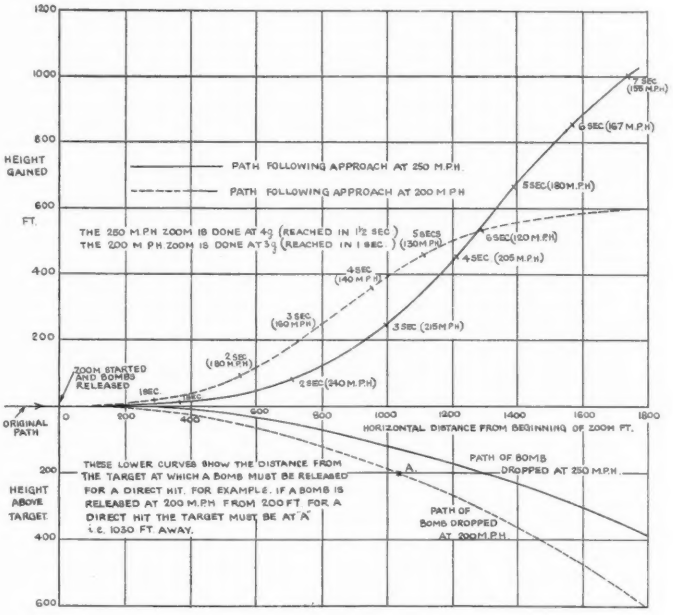

HEIGHT GAINED
FT.
PATH FOLLOWING APPROACH AT 250 M.P.H.
PATH FOLLOWING APPROACH AT 200 M.P.H.
THE 250 M.P.H. ZOOM IS DONE AT 4g (REACHED IN 1½ SEC.)
THE 200 M.P.H. ZOOM IS DONE AT 3½ (REACHED IN 1 SEC.)
ZOOM STARTED AND BOMB RELEASED
ORIGINAL PATH
HORIZONTAL DISTANCE FROM BEGINNING OF ZOOM FT.
THESE LOWER CURVES SHOW THE DISTANCE FROM THE TARGET AT WHICH A BOMB MUST BE RELEASED FOR A DIRECT HIT. FOR EXAMPLE, IF A BOMB IS RELEASED AT 200 M.P.H. FROM 200 FT. FOR A DIRECT HIT THE TARGET MUST BE AT 'A' i.e. 1030 FT. AWAY.
HEIGHT ABOVE TARGET
PATH OF BOMB DROPPED AT 250 M.P.H.
PATH OF BOMB DROPPED AT 200 M.P.H.
A

FIG. 6.8.

Ju. 88—Zooms at 200 m.p.h. and 250 m.p.h.

6.9. *Discussion.*

The Ju. 88 is obviously an extremely useful military machine, with good performance and load-carrying qualities and excellent manœuvrability for its size at high speeds. In spite of all the refinements provided by the designer to improve the trim and control characteristics, it is, however, not an easy aeroplane to operate, mainly owing to its high loading; inexperienced pilots must in particular take some time to get used to the approach and landing, especially with one engine dead. Its reputation as a somewhat " tricky " aeroplane may be clearly discerned from the following quotation, taken from an official German handbook:—

" Because of its special purposes as bomber and dive-bomber, the type Ju. 88 had to follow constructional principles which show several changes from what was normal hitherto.

" If the pilot bears this carefully in mind, the Ju. 88 presents no special difficulty; on the contrary, the pilot, after gaining experience, feels very comfortable even under difficult conditions and is enthusiastic about the fighting power of his aircraft."

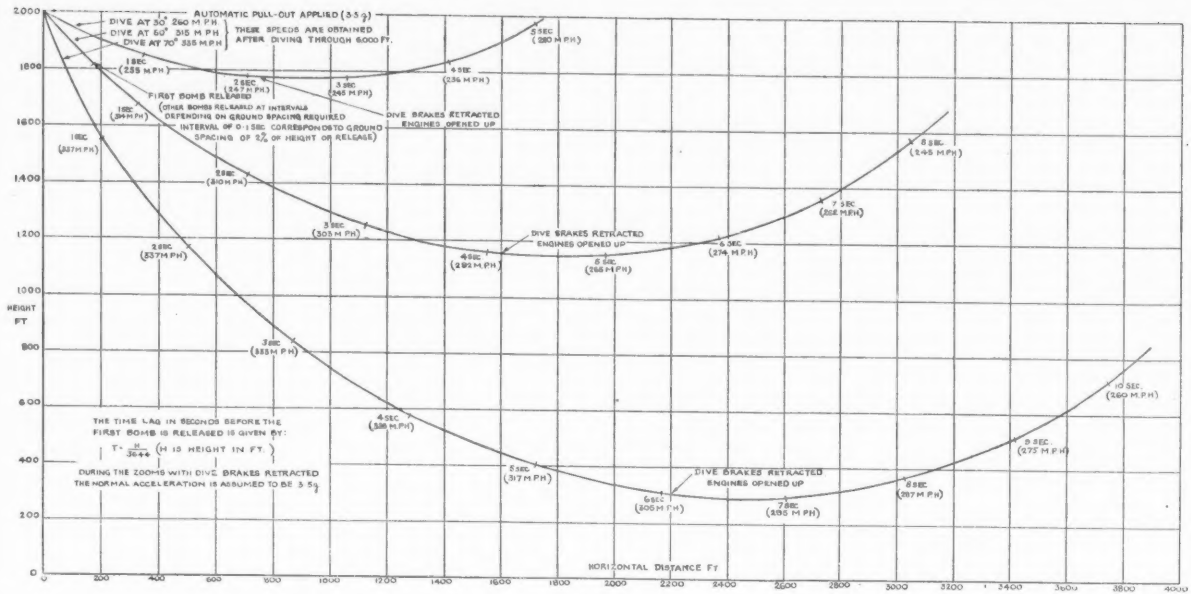


FIG. 6.9.

Ju. 88—Paths during Recoveries from Dive using the Automatic Pull-out.

TABLE 6.1.

JUNKERS 88 A-1 AERODYNAMIC DATA.

Wings.	
Gross area S sq. ft.	549
Span $2s$ ft.	59.8
Mean chord c ft.	9.18
Aspect ratio	6.5
Chord { Root ft.	11.76
Chord { Tip ft.	4.59
Thickness/Chord Ratio % Root	14.9
Thickness/Chord Ratio % Tip	11.7
Slots.	
None fitted.	
Flaps.	
Type	Slotted
Total area sq. ft.	66.2
Flap area/S	0.12
Flap chord/local chord	0.205
Flap span/$2s$	0.51
Maximum angle	52°
Dive Brakes.	
Outline area (each) sq. ft.	9.08
Span (each) ft.	8.60
Width ft.	1.1
Longitudinal Control.	
Gross tail area S' sq. ft.	113.6
Elevator area/S'	0.415
Tail arm/Wing chord l'/c	2.79
S'/S	0.205
Tail volume coeff. $S'l'/Sc$	0.575
Type of balance	Set back hinge and geared tab
Percentage balance %	22.5
Total tab area sq. ft.	5.3
Tab gearing	0.65 : 1
Maximum elevator angles { down	26°
Maximum elevator angles { up	40°
Stick gearing deg./inch	4.7
Directional Control.	
Fin and rudder area S'' sq. ft.	39.8
Rudder area/S''	0.417
Fin arm/semi-span l''/s	1.06
Fin and rudder volume coeff. $S''l''/S$	0.077
Tab area sq. ft.	2.84
Maximum tab angles, trim	±16°
,, ,, spring	±8.5°
Maximum rudder angles	±32°
Pedal gearing deg./inch	13.3
Lateral Control.	
Aileron area/S	Slotted
Aileron span/$2s$	39.8

Aileron area/S	0.072
Aileron span/$2s$	0.39
Aileron chord/local chord	0.23
Percentage balance %	27.7
Tab area (port only) sq. ft.	1.24
Maximum aileron angles	±20.5
Stick gearing deg./inch	1.7

PART II.

Engine Cooling.

7. General.

Current German aircraft cooling systems have several features of considerable interest to designers, and it has been thought worth while to examine these characteristics in some detail. To appreciate fully the significance of some designs, it is necessary to bear in mind that in the last few years there have been rapid developments in the technique of engine cooling in flight. These were heralded, in England, by the publication in 1935 of two papers, in the A.R.C. Reports and Memoranda series, by Meredith[1] and Capon,[2] outlining the basic principles of ducted cooling. A brief summary of these principles, which have now become almost instinctive to English aircraft designers, is as follows:—

To maintain constant engine temperatures over a range of flight speeds and engine powers, it is necessary to vary the configuration of the cooling system. Thus as flight speed increases it is necessary either to close the entry or exit of the duct leading the cooling air to the cooling surfaces, or to vary the area of cooling surface. Of the various alternatives control of the cooling by variation of the exit area is most efficient, *i.e.*, permits the smallest drag to be attained for any given heat dissipation and flight speed. In the worst conditions for cooling, with large engine power at low flight speed, the exit to the cooling air duct is opened fully, and sufficient area of cooling surface must be provided to give adequate cooling in these conditions. At higher speeds the exit is then progressively closed so as to reduce the ratio of velocity at the cooling surface to flight speed. The air pressure at the cooling surface at high speeds is considerably greater than that in the outside air-stream; the addition of heat to the cooling air at increased pressure operates as a relatively inefficient heat engine, and a small but appreciable drag reduction results at high speeds.

In applying these principles to practical cooling systems, as is well known, a major difficulty arises. At high speeds, when it is particularly necessary to avoid losses, it is unavoidable that the entry duct, leading the air from the outside stream to the radiator or the engine fins, should be a region of steadily increasing pressure. Such a region is of course conducive to separations and consequent large losses, and in fact the whole design of the cooling system centres around the correct location and shaping of the entry duct. The problem is at its most critical when the entry is located well aft on the surface of fuselage or wing, taking in the already thick boundary layer on this surface; for such a boundary layer separates readily and losses are almost unavoidable.

Apparently German aircraft designers began to realise these facts in about 1937. In that year an article by Barth[3] was published in the German technical press which reiterated the principles laid down by the English workers. It is not clear whether this was an independent study, or whether it was inspired by the papers of Meredith and Capon. The fact remains that once the facts were apparent to German aircraft designers they were not slow to take advantage of them. This will be clear from the following discussion of the characteristics of a few typical engine installations. It is possible that in 1939 German designers did not appreciate sufficiently the importance of careful entry design to avoid

losses; but in at least one instance a subsequent redesign of the whole entry duct has shown a growing awareness of this problem.

8. Liquid-Cooled Engine Installation.

8.1. *Cooling system on Ju. 88-Jumo 211 B/1 engines.*

The early version of the Junkers Ju. 88 has a cooling system which is of some interest, as no similar installation has been tried in this country. (Later Ju. 88 aircraft are fitted with B.M.W. 801 engines with cowl entry fans to supply cooling, as described in para. 9 below.) The radiator and oil-cooler matrices are assembled as segments around the reduction gear of the Jumo engine, and are surrounded by a circular cowling very like that of the ordinary air-cooled radial engine. The air intake forms one of the segments. The cooling air enters between the propeller blade roots, as on a radial engine, and is discharged from a slit of variable area about 2 ft. aft of the nose of the nacelle. The aim in this installation has clearly been to devise a ducted system according to the principles outlined above, and at the same time to maintain a compact self-contained engine installation. From our knowledge of radial engine cooling problems, however, it is apparent that there are losses at the entry owing to separation of the flow from the central propeller boss and reduction gear fairing, aggravated by the poor total head of the air passing through the propeller blade roots. The mean total head of the air at the radiator matrix is probably about 0.8 of that in the outside stream, and at the top speed of the aircraft the drag associated with this separation is likely to be at least as great as that of the radiator and oil-cooler matrices.

It is the existence of this separation around the central boss—which is extremely difficult to avoid—which has prevented the use of a similar system on English liquid-cooled engines. It will be appreciated, however, that it permits the use of a very much larger radiator matrix than is usual in current radiator designs, without much increase in drag of the external cowling surfaces, and it may therefore have some application to engines of greatly increased power, particularly if used in conjunction with a cooling fan.

8.2. *Radiators on Me. 109E, Me. 110.*

The original radiators on Me. 109E are another example of a system in which losses in the entry duct have been neglected. This aeroplane has a small radiator on each wing, and an oil-cooler under the fuselage. A section of one radiator is shown in Fig. 2.5. It will be seen that the radiator is installed on the wing under-surface as far aft as the flap permits, so that it suffers from the fact that it takes in the already thick boundary layer from the wing surface ahead. To make matters worse it is very deeply recessed into the wing, so that the flow at the entry, already very critical, is expected to turn a very sharp corner. In fact, the flow separates and most of it passes through the lower half of the radiator. This is illustrated by the curves of Fig. 8.1, which are abstracted from English tests of an almost identical system. It will be seen that over the upper 60 per cent. of the radiator matrix the total head of the cooling air just in front of the matrix has dropped to only 0.4 of its initial value, $\frac{1}{2}\rho V^2$, in the outside stream. At the top speed of Me. 109E, 350 m.p.h., at 18,000 ft., the passage of the cooling air over the matrix surface is responsible for a drag equivalent to 0.6 per cent. of the engine power; the additional loss of total head in front of the radiator puts up this loss to 2.9 per cent. of the engine power.

The losses in the radiator system of Me. 110 are very similar to those of Me. 109E. In Me. 110 the radiator for each engine is situated on the wing under-surface just outboard of the nacelle (Fig. 31, 3.2). Again the entry is well back on the surface, and the radiator is recessed into the wing so that separation and large entry loss are inevitable.

It is surprising that although larger losses have been permitted to occur in the entry, the exit design has been considered fairly carefully. In both Me. 109E and Me. 110 the landing flap behind the exit has been appreciably bulged on the lower surface. The aim in this is presumably to enable the small exit area required for high speed flight to be obtained without too great an upward sweep of the fairing lines of the radiator cowl external shape; this would avoid the possibility of separation on the external surface aft of the plane of the matrix.

It seems possible that the position of the radiators on Me. 109E and 110, well aft on the wing undersurface, was chosen primarily for reasons for vulnerability. Their situation is such that they are well protected from fire from ahead, the most likely direction when attacking slower aircraft. Whether the German designer was aware of the large loss which this entailed, and deliberately sacrificed aerodynamic efficiency for better protection, is a matter for speculation. Having regard to the absence of armour on these aeroplanes at the beginning of the war, it seems unlikely.

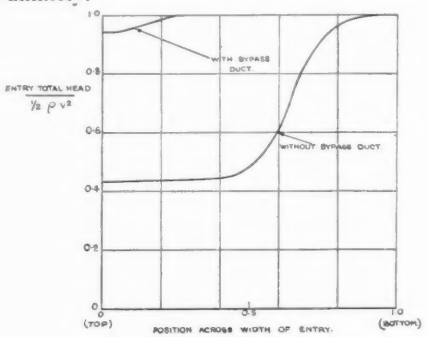


FIG. 8.1.

Vertical Distribution of Entry Loss on Me. 109F Radiator.

8.3. *Redesigned radiator on Me. 109F.*

On the Me. 109F a complete redesign of the radiator system was undertaken, with the object of reducing the losses in the radiator entry. As on earlier versions, there are two small radiators, one on each wing, well aft near the trailing edge, and a single oil-cooler under the fuselage. A section of the radiator duct and landing flap is shown in Fig. 8.2.

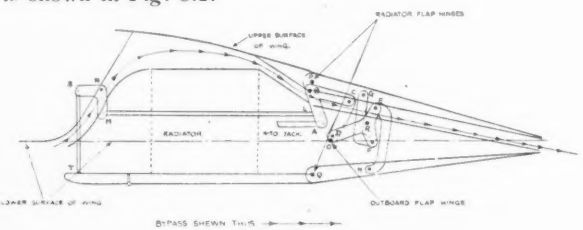


FIG. 8.2.

Diagrammatic Sketch of Me. 109F Radiator.

It will be seen that the duct exit is now at the wing trailing edge, interrupting the main wing flap over a small part of its span. Control of exit area is automatic; a thermostat between the header tank and the radiator operates a hydraulic jack which opens or closes two louvers forming the upper and lower

surfaces of the duct at the exit. The linkage which accomplishes this can be seen in Fig. 8.2; to open the exit louvers, the jack pushes in a rearward direction on the bell-crank ABC at A. This crank is pivoted to the wing at B, and a floating link CD transfers the motion to a second crank DEF, which then rotates in a clockwise direction around its pivot R. Further links, FG, EH, utilise this rotation to open the upper and lower louvers equally, about their respective hinges P and Q.

When the landing flap is lowered, both louvers are lowered together so as to maintain practically constant exit area. This is achieved by attaching the pivot R of the second crank to the landing flap outboard of the radiator, and making driving point D of this crank lie approximately on the hinge line O of the landing flap. In the example examined, D and O did not exactly coincide, so that when the landing flap was lowered the cooling louvers opened slightly.

The exit louvers are of quite large chord and are completely unbalanced; when nearly closed there is a very high pressure in the duct, almost equal to pitot pressure, tending to force them open. It will be observed that the linkage is so designed that the leverage becomes progressively greater as the louvers are closed; in fact, when the exit is fully closed, the levers FG, EH are approaching a "dead centre." This permits the exit to be closely fully at high flight speeds without the use of an excessively large jack.

Passing above the main radiator duct is a subsidiary duct, commencing just inside the entry and continuing to the wing trailing edge. Its purpose is to avoid the loss from separation of the flow from the upper surface of the main duct inside the entry, by by-passing the troublesome boundary layer from the wing lower surface ahead of the entry. The by-pass duct is almost unobstructed and has no regions of very high positive pressure gradient, so there is no large loss due to separation of the flow at any point. At the entry the by-pass is rather more than 1 in. wide, and it maintains this width over most of the passage, including the exit.

Tests show this type of radiator to be quite effective. Fig. 8.1 applies to a radiator almost identical with that of the Me. 109F; it shows that the loss of total head in the entry, which in the 109E was almost 60% of $\frac{1}{2} V^2$ over the upper portion of the matrix, has been reduced almost to zero by the use of the by-pass. The resulting saving in drag is equivalent to about 2% of the engine power at the top speed of the aeroplane; there is a slight drag increase due to the loss of total head of the stream through the by-pass duct, but this is small in comparison with the saving in drag which it effects.

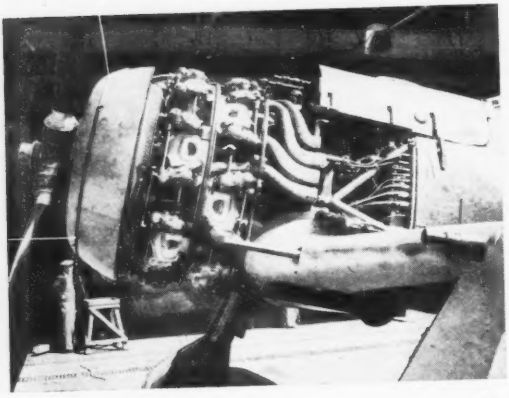
A final point of interest on the Me. 109F radiator is that the entry area has been made variable. A link LM is taken forward from the exit control mechanism, and operates an entry louver at T through a bell-crank MNS. The entry area is thus increased as the exit louvers are opened. In model tests of very similar duct systems, very little case can be made for this added complication. When the entry is open, stalling from the outer surface of the lip takes place, and the external drag of the radiator is much increased. If the entry is shaped so as to avoid this separation when its area is large, it is not difficult to ensure that it will function without loss, with the same area, when the flow through is reduced by closing the exit down.

9. B.M.W. 801 ENGINE ON FOCKE-WULF 190 AND DORNIER 217.

9.1. *General description.*

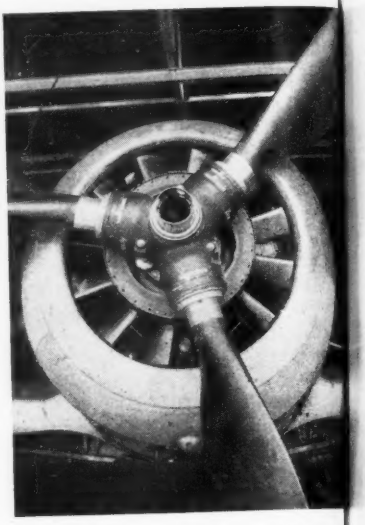
The B.M.W. 801 radial air-cooled engine first made its appearance on Dornier 217 and Focke-Wulf 190. It presents many novel features, including the adoption of several new principles in engine cooling. An overall view of the installation on F.W. 190 is given in Figs. 4.1 to 4.4, 9.1 and 9.2 and a section of the engine and cowl in Fig. 9.3. The cooling fan, geared-up to run at 1.7 times the crankshaft rotational speed, is clear from these figures. Its dimensions, etc., are

given in the table below. In the earlier F.W.190 aeroplanes, there was no control of exit area; the cooling air escaped from several slots in the cowling behind the engine, and the total exit area was about 1 sq. ft. Later versions of the aeroplane have small louvers on the sides of the fuselage behind the engine, which permit the exit area to be varied by the pilot from 1.1 to 1.8 sq. ft. On the Dornier 217, the cooling fan is identical with that used on F.W.190, but the exit area control is very different. It consists of a ring round the cowling at the gill exit, which can be moved fore and aft to change the exit area from a minimum of 1.2 sq. ft. to a maximum of 3.7 sq. ft.



[*Crown copyright reserved.*]

FIG. 9.1.



[*Crown copyright reserv*

FIG. 9.2.

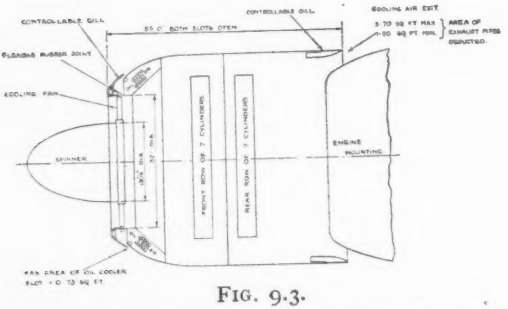


FIG. 9.3.

Diagrammatic Arrangement of B.M.W. 801 Engine.

Another novel feature of the B.M.W. 801 engine is the method of cooling the oil. The oil-cooler consists of a number of finned tubes contained in the nose of the cowling, as shown in Fig. 9.3. Air enters from the high-pressure region between the fan and the engine cylinders, passes forward through the cooler, and is ejected at an annular slot on the cowl surface very near the nose. The

exit area is variable, up to 0.73 sq. ft., by fore-and-aft movement of the annular ring which forms the nose of the cowl.

TABLE.

DETAILS OF B.M.W. 801 COOLING FAN.

Blade width	$b = 5.8$ in.	Mean chord $c = 3.75$ in.	
Mean diameter ...	$D = 2.18$ ft.	Entry area $S = 3.32$ sq. ft.	
Number of fan blades	$N = 12$	Mean blade angle = 19.25 degrees (almost constant along blade).	

Fan solidity $\frac{N.bc}{S} = 0.56$

Gap between blade tip and cowling = 0.3 in. (roughly)
Maximum crankshaft speed: Do. 217 – 2,700 r.p.m. F.W. 190 – 2,500 r.p.m.
Corresponding fan speed. (1.7 x crankshaft speed): Do. 217 – 4,250 r.p.m. F.W. 190 – 4,600 r.p.m.

The attraction of this scheme to the designer lies in the very high sections which are present on the external surface of the typical radial engine cowling just behind the plane of the entry. A cooling air exit in this region is at a static pressure, which can be as low as 0.6–0.7 of $\frac{1}{2}\rho V^2$ below the static pressure in the undisturbed air. As a result, the maximum cooling flow through the system is some 30% greater than would be obtained if the exit were located in a more conventional position where the static pressure is not appreciably below the undisturbed value. There is a drag associated with the flow disturbance over the outside of the cowling due to the issuing cooling air, but provided that the exit is well forward on the cowl—ahead of the minimum pressure point on the cowl profile—this drag component is small.

9.2. *Performance of cooling fans.*

9.21. *Flight tests on F.W. 190.*

The geared-up fan on B.M.W. 801 has attracted considerable attention from designers in this country, and to obtain some idea of its characteristics, some measurements have been made in flight on a later version of F.W. 190 (with variable exit area). These consisted in determination of the total head and the swirl of the cooling flow behind the fan at low (climbing) speeds and during the ground run, by installing calibrated triple-tube yawmeters. These were fitted one inch from the tips and one inch from the roofs of the fan blades, so that some idea of the variation across the fan blade could be obtained.

The results, for different values of the engine r.p.m., and with the greatest possible exit area of 1.8 sq. ft., were as follows:—

V m.h.p. T.A.S.	Engine r.p.m.	Total head behind fan less total head in main stream (in of water).		Angle of swirl behind fan relative to axis of engine (degrees).	
		1 in. from root	1 in. from tip	1 in. from root	1 in. from tip
220	2,015	0.1	0.05	45	45
166		1.6	0.05	45	45
117		5.8	3.9	57	45
0		8.2	11.3	64	61
206	2,500	3.9	0.2	45	45
133		10.4	8.2	57	45
90		11.3	12.0	53	64
0		12.7	16.3	65	61
0	2,300	10.0	15.6	64	61
0		10.2	15.6	65	61

These results can all be combined into a single curve; for, like a propeller, the fan characteristics are a function of the ratio V/nD, where V is the true air speed and n is the fan's rotational speed. Thus the curve of Fig. 9.4 gives the value of (total head behind the fan less main stream total head) as a function of forward speed at ground level, 2,500 engine r.p.m. It is obtained from the experimental results at the same V/nD by assuming the total head increment to be proportional to σV^2, where σ is the relative density at the height of the tests. The characteristics of the fan at any speed, height and r.p.m. can clearly be obtained from this curve by a reverse process.

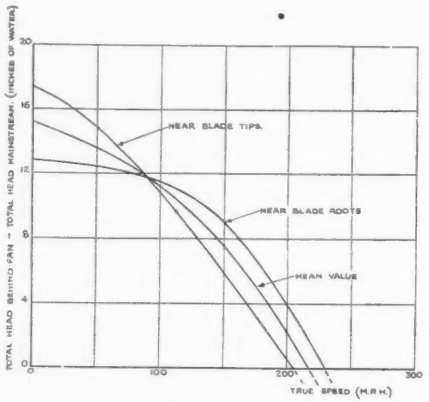


FIG. 9.4.

Total Head Rise behind Fan on B.M.W. 801 Engine.

For a full appreciation of the performance of the fan it is of course necessary to know more than merely total head and swirl behind it. The characteristics depend also upon the cooling flow through the fan and the losses and swirl produced by the propeller and spinner ahead of it; and they include as an all-important factor the power required to drive the fan. Unfortunately, the large number of cooling air exits, including also the engine exhausts, prevented the determination of cooling flow with any accuracy; and flights with the fan removed, to check the contribution of the propeller, could not be made because of engine overheating. For these reasons, the measurements have been supplemented by a rough estimate of the remaining characteristics, based on simple blade-element theory.

If a typical value of 0.3 x $\frac{1}{2}\rho V^2$ is assumed for the drop in total head ahead of the fan due to the separation which usually occurs at the propeller spinner, and to the cylindrical propeller blade roots, then the measured values of total head behind the fan may be correlated with the remaining characteristics as follows:—

GROUND LEVEL CONDITIONS AT 2,500 ENGINE R.P.M., EXIT AREA 1.8 SQ. FT.

Flight speed. V m.p.h.	Loss in total head up to fan.	Total head rise through fan.	Measured total head rise from main stream to rear of fan.	Cooling flow. cu. ft./sec.	Mean entry velocity. ft./sc.	Power required to drive fan. H.P.
	Inches of water (mean).					
200	6	8	2	420	125	35
100	2	13	11	380	115	50
0	0	15	15	360	105	55

This table shows that as the flight speed increases the total head provided by the fan steadly diminishes. At about 220 m.p.h. it has been reduced from its static value of 15 in. of water to a value just sufficient to offset the loss in the entry ahead of the fan, so that the total head behind the fan is the same as in the main stream. At rather less than 300 m.p.h. (extrapolating the above figures) the fan provides no increase in total head whatever. The power extracted from the engine to drive the fan also diminishes with increasing flight speed.

This change in the fan total head and power absorption arises because the steadily increasing cooling flow through the system with increasing forward speeds reduces the effective incidence of the fan blades and so decreases both the torque and thrust of the fan. If the exit area is varied with changing flight speed so as to keep the quantity of cooling air constant, then the fan conditions also stay constant and total head rise and power absorption are independent of flight speed.

The large swirl which occurs behind the fan, as measured in the flight tests, is noteworthy. It is, of course, the inevitable result of applying a large torque, through the fan, to a fairly slow-moving stream of cooling air. It is a matter for speculation whether this swirl justifies the addition of straightening vanes behind the fan. Apparently, in the German opinion, straightening vanes are not worth while; and, furthermore, they have not considered it necessary to rotate the propeller and the cooling fan in opposite directions. Such a step would have had practically the same effect as straighteners in reducing considerably the final swirl just ahead of the cylinders.

It would be possible, of course, to design the engine baffle as straighteners, but there is no sign of this on B.M.W. 801. The rotational energy is apparently dissipated in separations on reaching the cylinders and baffles. It is conceivable, however, that the swirl, in spite of being dissipated in this manner, performs useful work in cooling the front of the cylinders.

9.22. *General consideration of fan cooling.*

It is useful to consider at this point whether fan cooling is to be preferred to unassisted cooling as used at present on most aeroplanes. The fan has an obvious advantage in augmenting the flow at low flight speeds and for ground running. The B.M.W. 801 fan, for instance, supplying 360 cu. ft./sec. of cooling air at a pressure of 15 in. of water, is sufficiently powerful to cool the engine at full power during the ground run.

It is easy to see that the fan has also some advantage in providing more efficient cooling at all flight speeds. For during flight with unassisted cooling, the engine requires a cooling flow F and causes a drop H in the total head of this flow. The power absorbed in cooling consists of a portion $F.H.$ at the engine, plus a further loss in the wake which results from the fact that the expelled cooling air, of low total head, has a velocity relative to the main stream and some kinetic energy is therefore wasted. Jones' formula expresses the whole power loss as

$$\rho V^2 F(1-\sqrt{\{1-H/\tfrac{1}{2}\rho V^2\}}).$$

The whole of this power loss, of course, appears as drag, and has to be supplied by the propeller at an efficiency of about 80%. Thus the overall efficiency of the cooling process without fan assistance is:—

$$\frac{\text{essential cooling power } (FH)}{\text{engine power required}} = 0.80 \times \frac{FH}{\rho V^2 F(1-\sqrt{\{1-H/\tfrac{1}{2}\rho V^2\}})}.$$

Typical values of $H/\tfrac{1}{2}\rho V^2$ are 0.3 at top speed, 1.0 at best climbing speed; thus the overall efficiency of unassisted cooling, defined as above, is about 75% at top speed and 40% on climb.

Now suppose that a fan is provided which supplies the whole of the total head H. The cooling air will then be expelled at full flight total head and there will be no internal drag or wake loss. The efficiency of cooling, as defined above, is then

$$\frac{F.H.}{\text{fan power}} = \text{work done by fan/fan power.}$$

This is, of course, the fan efficiency as usually defined. For a single-stage axial fan of the type considered, it should not be less than 0.8; wind tunnel fans, for example, have usually an efficiency of 0.9 or more. Thus fan cooling is slightly more efficient than unassisted cooling at top speeds, and is about twice as efficient on the climb.

On a typical radial engine of 1,300 h.p., it is estimated that the greater efficiency of fan cooling represents a saving of about 1 lb. at 100 ft./sec. in drag at top speed, and 12 lb. at 100 ft./sec. on climb.

These considerations have not included the effects of the issuing stream of cooling air on the aeroplane surfaces behind the engine. It is known, for instance, that when a conventional radial engine is installed with its gill exit only a few inches forward of the wing leading edge, the flared louvers as usually fitted to the exit can have in their open position a devastating effect upon the flow over the wing, particularly at the higher incidences associated with climb and cruise of a fully-loaded heavy bomber. The B.M.W. 801 installation on Do. 217 has avoided this possibility; there are no flared louvers and the total head of the cooling air emerging from the exit is almost undiminished.

A very strong case can thus be made for the application of a fan of the E.M.W. 801 type to the cooling of engines in heavy, fairly low-speed bombers which have to cruise at comparatively high power and high lift coefficients. It it more difficult, however, to decide on what grounds its added complication could be justified in the case of the F.W. 190. Adequate cooling on the ground has of course to be provided, but should be quite possible without the aid of a fan if the maximum exit area was increased.

The reason for its application to F.W. 190 may lie in the very small variation of cooling flow with forward speed, at a fixed exit area, which it makes possible, as shown in the tables above. This means considerable simplification from the pilot's point of view, since he is only required to move the exit-control on comparatively few occasions. In fact, as mentioned earlier, the first F.W. 190 to arrive in England had no control whatever; and even now the range of exit area possible is very small compared with more conventional cooling systems, and may only have been provided to meet varying conditions of climate.

References.

1. F. W. Meredith. Cooling of aircraft engines (with special reference to ethylene glycol radiators enclosed in ducts). R. & M., 1683. Aug., 1935.
2. R. S. Capon. The cowling of cooling systems. R. & M., 1702. March, 1936.
3. W. Barth. Examination of the resistance and airflow through various cowled radiator installations. *Luftfahrtforschung*, Vol. 14, No. 6, June, 1937. (Translated by W. J. Stern. A.R.C. 3146, Aug., 1937.)

PART III—View.

10. General.

Some explanation is necessary for the inclusion of a chapter on view in an account of the aerodynamic features of German aircraft. The problem of providing good all-round view is of course of tremendous importance in military aircraft—a lot depends upon seeing your adversary before he sees you. But it is unfortunate that clearness of vision from an aircraft is not a thing which can be measured, or its quality expressed in terms of some convenient index. It must be assessed by that most uncertain criterion, the impressions and opinions of the operational pilot.

The designer, attempting to provide good view, soon finds this requirement demanding sacrifices in the aerodynamic efficiency of the aeroplane. Now the aerodynamic qualities are readily measured, in terms of the performance of the aeroplane, and good performance is the chief aim of practically every designer of military aircraft. It is not surprising, then, that in the conflict between aero-

dynamics and view, the latter should frequently take second place. For his aerodynamics there is a perfectly definite criterion for the view which he provides no adequate measure. It is doubtful whether anyone in the aeronautical world at the moment can indicate, even roughly, where the division between the two requirements can be made. Even the pilot of an F.W. 190, with an ominous Spitfire fluttering around his tail, would find it difficult to decide whether he would rather have another ten degrees of view to his rear or another 5 m.p.h. added to his speed. In fact, following the time-honoured tradition of the Service, he would want both!

The interest in the German aircraft, from this standpoint, lies in the fact that their designers have chosen to sacrifice rather more to provide good view than we should expected. Their designs of windscreen and cabin show signs of having had considerable attention to improve the pilot's vision, especially on the fast single-seater fighters. Only a few examples are shown here to demonstrate this fact.

The authors are indebted to S/L Olenski, of the Polish Air Force, for most of the illustrations on this subject.

11. Examples of View from German Aircraft.

11.1. *View forward and upward.*

Looking at an early German fighter, the Me. 109F, the most obvious feature is the large number of flat panels (Figs. 11.1, 11.2). They are set in metal frames with a certain amount of rounding of the corners, but the general impression is that the cabin shape is much more angular than corresponding English designs. Of course, the use of flat panels considerably assists the view, it gives very little distortion, and it avoids the distressing highlights and bright

[*Crown copyright reserved.*]

FIG. 11.1.

[*Crown copyright reserved.*]

FIG. 11.2.

patches which result from the focussing effects of curved panels. But it has to be paid for by increased drag, largely arising from disturbances at the sides of the front screen. At the top speed of a Me. 109F its cost is roughly equivalent to 3 m.p.h. in speed; on a faster aircraft of 450 m.p.h. at 20,000 ft., the corresponding reduction would be about 9 m.p.h.

The use of flat panels is not confined to German fighters. The nose of the Ju. 88 is a good example of its application to a bomber (Fig. 6.2). The drag of this nose, compared with a completely faired nose, is completely negligible; on the other hand, there are so many panel frame members that the view is somewhat interrupted, and a curved perspex panel would not be appreciably worse. The construction of the Ju. 88 nose is extremely interesting; the whole complicated framework is a single casting.

Returning to the Me. 109F, the cabin shown in Figs. 11.1 and 11.2 has two serious defects. The first is that the flat panels are not made of glass, but of a plastic. As a result the surfaces scratch very easily, and after a short period in service they become covered with a network of very fine scratches, which seriously impair visibility. This can be seen particularly in Fig. 11.2 on looking through the double thickness of side panel. To overcome this defect, a direct vision opening is provided in the left-hand front corner panel (Fig. 11.1) and the main side panels and the top panel can be slid back so as to give an uninterrupted view.

On the F.W. 190, which is of course of much later design, the forward side panels and the front screen are again flat, but are made of glass. The junctions of these panels are even less rounded than those of Me. 109 F (Fig. 11.3).

[*Crown copyright reserved.*]

FIG. 11.3.

The second fault of the Me. 109F is that there is an almost complete absence of view to the rear. Here, again, the F.W. 190 is a great improvement over the Me. 109F. In fact, the rear view from the F.W. 190 is so great a step forward, compared with earlier types, that it is worth considering in some detail.

11.2. *Rear view from* F.W. 190.

Fig. 11.4 is an attempt to show what the pilot of F.W. 190 can see by turning in his seat. It demonstrates the exceptionally wide expanse which is visible without distortion, and with only a mild amount of interference from internal reflections. A good deal has been done to permit the pilot to take full advantage of this view. The armour plate, visible in Fig. 11.4, has been cut away as much as possible so that the pilot can see round it, the harness over the pilot's shoulders is of special design, permitting him to turn his shoulders when he desires. The advantage, which this gives in any combat, and the freedom from surprise attack from the rear, is obvious.

Two factors contribute to this good rear view. The tail of the fuselage (Fig. 4.3) is cut away behind the cabin, both on top and at the sides, so that it does not impede the view to any appreciable extent. The sliding hood through which the pilot looks to the rear is a large moulding of very good quality. Whilst no aerodynamic expert could object to its shape from the point of view of affecting the performance of the aeroplane, yet it is nevertheless quite well designed from the optical standpoint. The line of sight in looking to the rear is at an unusually large angle to the surface, so that the distortion produced by the moulded surface is unusually low.

There is no doubt that the F.W. 190 pilots appreciate the merits of the rear view from their aeroplane. Judging from the specimens received in England, extreme care is taken over the cleaning and maintenance of the sliding hood. The aircraft shown in Fig. 10.3, for instance, had only arrived in England a few hours before the photograph was taken; it will be seen from the illustration that the hood was completely devoid of dirt, grease or blemishes.

[*Crown copyright reserved.*]
FIG. 11.4.

Finally, although not an aerodynamic matter, the methods employed in the F.W. 190 to eliminate internal reflections of the instrument board, etc., in the transparent surfaces are worth mention. Everything possible inside the cockpit is painted dull black; and to avoid reflection of the instruments themselves, an overhanging coaming (Fig. 10.3), protruding some 6 in. out from the board both on top and at the sides, has been provided.

PART IV.

12. DISCUSSION.

From the handling viewpoint the aeroplanes discussed are very much a mixed bag. The stars are undoubtedly the F.W. 190 and Ju. 88. Both of these excel in manœuvrability at high speeds, a very great asset in any military aircraft, either fighter or bomber.

None of the aeroplanes considered exhibit any revolutionary control features, the only completely novel device brought to light being the Ju. 88 swinging aileron weights. The German designers, however, clearly seem imbued with a creditable determination to make the aerodynamics fit the pilot, rather than to force the pilot to put up with the aerodynamics. This is shown by their willingness to face mechanical complication in order to ease the pilot's burden; gearing the wing flaps to the moving tail plane, drooping the ailerons with the flaps, fitting the rudder with a spring tab, automatically maintaining constant engine temperature by thermostatic control or the use of a fan, are typical examples.

In fighter design an attempt has obviously been made to free the pilot as much as possible from any distractions which will interfere with his primary job of getting his sights on the target. Ideally the fighter pilot should not have to bother about adjusting elevator and rudder trimmers during a combat; the stick and pedal forces should be so small during wide variations of speed and power as to need no assistance from ancillary controls. The Me. 109 designer attempted to do without a rudder trimmer, but penalised his aeroplane thereby. The F.W. 190 designer, on the other hand, succeeded; the rudder trimmer has been deleted without seriously hindering the pilot, and at the same time longitudinal stability, elevator heaviness, etc., has been so adjusted that recourse need not be made to the elevator trimmer when manœuvring.

A wider issue may be raised in conclusion. When considering the ups and downs of our battle with Germany for technical excellence, particularly in relation to fighter aircraft, one is struck by the fact that at any particular phase the main cause for jubilation (or, alternatively, worry) is often because in *one* particular feature our own aircraft (or that of the enemy) is markedly superior. That feature may be exceptional top speed, unusually high rate or angle of climb, marked acceleration in the dive, exceptional aileron control in the dive, insusceptibility to negative " g," small turning circle, and so on. Whatever it may be, the pilot quickly gets skilled in its exploitation, so that for a while it determines the whole pattern of air combat.

Compromise is a revered word in aircraft design. With the above background in mind one wonders whether it would not be a good thing, when starting a new design, to fix on just one particular feature in which it is determined that the design should excel; and subsequently, however difficult, while compromising, as of course one must, between all the other varied factors, let *nothing* stand in the way of the chosen characteristic coming out on top. The relative merits of such an " unbalanced " design and a more conventional " balanced " layout is a fruitful topic for controversy.

ACKNOWLEDGMENTS.

The authors would, in conclusion, like to pay tribute to the pilots who undertake the flight testing of German machines at our experimental stations. As may well be imagined, even when it is known that precautions have been taken against untoward incidents, piloting an enemy aircraft over this country, while concentrating on instruments and accuracy of flying during performance and handling tests, is not conducive to peace of mind. Thanks are also tendered to our colleagues on the scientific and technical staff of the R.A.E. for assistance in the preparation of this paper.

APPENDIX.

NOTE ON THE METHOD OF LIGHTENING AILERONS BY SWINGING WEIGHTS IN THE WING TIPS, AS USED ON THE JU. 88.

1. DESCRIPTION.

This ingenious device was brought to light from an examination of a crashed Ju. 82. The general features of the scheme can be seen from Fig. 1. Inside each wing, near the tip, a weight is mounted on an arm OW, which pivots about a vertical axis at O. This arm is mechanically coupled to the ailerons in such a manner that when the ailerons are central it lies parallel to the span, with the weight inboard. On displacing the ailerons the arm swings out by an amount proportional to aileron displacement. The rolling of the aeroplane produces a centrifugal force on the weight which tends to displace OW still further, and thus reduces the stick force needed to hold the ailerons over.

Cursory examination immediately indicates that the centrifugal force on the weight is proportional to p^2 and hence to ξ^2; while its moment about O varies as $\sin \xi$. Hence the lightening effect varies as $\xi^2 \sin \xi$, or ξ^3 approximately (see

Fig. 1.). The device should thus be extremely powerful in reducing stick forces for large aileron angles.

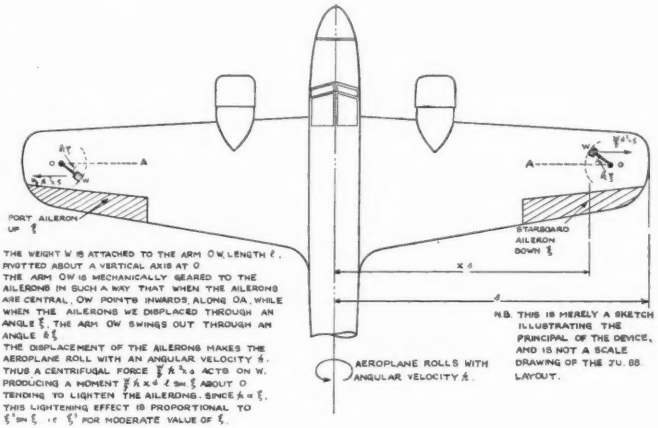

PORT AILERON UP ξ
THE WEIGHT W IS ATTACHED TO THE ARM OW, LENGTH ℓ. PIVOTTED ABOUT A VERTICAL AXIS AT O. THE ARM OW IS MECHANICALLY GEARED TO THE AILERONS IN SUCH A WAY THAT WHEN THE AILERONS ARE CENTRAL, OW POINTS INWARDS, ALONG OA, WHILE WHEN THE AILERONS WE DISPLACED THROUGH AN ANGLE ξ, THE ARM OW SWINGS OUT THROUGH AN ANGLE kξ. THE DISPLACEMENT OF THE AILERONS MAKES THE AEROPLANE ROLL WITH AN ANGULAR VELOCITY ṗ. THUS A CENTRIFUGAL FORCE W/g x ṗ²x² ACTS ON W. PRODUCING A MOMENT W/g x ṗ² x² ℓ sin kξ ABOUT O TENDING TO LIGHTEN THE AILERONS. SINCE ṗ ∝ ξ, THIS LIGHTENING EFFECT IS PROPORTIONAL TO ξ² sin kξ i.e. ξ³ FOR MODERATE VALUE OF ξ.
STARBOARD AILERON DOWN ξ
x d
d
N.B. THIS IS MERELY A SKETCH ILLUSTRATING THE PRINCIPAL OF THE DEVICE, AND IS NOT A SCALE DRAWING OF THE JU. 88. LAYOUT.
AEROPLANE ROLLS WITH ANGULAR VELOCITY ṗ.

FIG. A1.

Inertia Device for Lightening Ailerons.

2. THEORY.

Referring to Fig. 1, let

ξ = aileron displacement (radians).
$k\xi$ = corresponding angular displacement of the weight.
W = weight at the end of each arm (kb.).
l = length of arm OW.
$H = \overline{W}_1$ (lb. ft.).
S, s = gross wing area and semi span.
xs = distance of weight from centre line of aeroplane.
$S_\zeta c_\zeta$ = area and chord of an individual aileron.
p = steady rate of roll (radians/sec.) produced by ailerons at $\pm\xi$.
V = true airspeed (ft./sec.) = relative air density $V_1 = V\zeta\sigma$.
c_1 = overall rolling moment coefficient produced by two ailerons at $\pm\xi$.
l_p = damping coefficient in roll.
b_2 = variation of aerodynamic hinge moment coefficient with ξ.
K = " response factor," modifying b_2 to allow for the " b_1 effect " (see reference 2).

For simplicity we will assume that there is no differential (ailerons at $\pm\xi$). We have

$$\left(\frac{ps}{V}\right)l_p + \lambda c_1 = 0^* \qquad . \quad . \quad . \quad . \quad (1)$$

λ is a constant, average value 0.8, which allows for reduction in c_1 due to sideslip, etc.

$$\text{and } c_1 = -C_2\xi \qquad . \quad . \quad . \quad . \quad (2)$$

*At very high speeds this equation must be altered to

$$\left(\frac{ps}{V}\right)l_p + \lambda\left(1 - \left(\frac{V^2}{V_r^2}\right)\right)c_1 = 0$$

where V_r is the reversal speed, to allow for the reduction in rolling power caused by the wing twist which occurs when the ailerons are applied.

where C_2 is a constant, given approximately by

$$\left.\begin{aligned} C_2 &= \bar{\sigma}(0.2, +1.5E) \text{ sealed ailerons} \\ C_2 &= \bar{\sigma}(0.1 + 1.0E) \text{ unsealed ailerons} \end{aligned}\right\} \quad . \quad . \quad . \quad (2a)$$

$\bar{\sigma}$ being aileron span/s, and E aileron chord/wing chord.

$$\text{Thus } p = \left(\frac{\lambda C_2}{l_p}\right)\left(\frac{V}{S}\right)\xi$$

$$= A\,\frac{V}{S}\,\xi \quad . \quad . \quad . \quad . \quad (3)$$

$$\text{where } A = \frac{\lambda C_2}{l_p}$$

Due to the roll of the aeroplane each weight will experience a lateral acceleration p^2xs. The moment produce about o (Fig. 1) will thus be

$$p^2xs\left(\frac{H}{G}\right)\sin k\,\xi$$

Since m is the aileron/stick gearing, the weight/stick gearing will be km. Thus, if P_{wt} is the overall stick force produced by the two weights, we have

$$P_{wt}\,2 \text{ km. } p_2x\,s = \left(\frac{H}{g}\right)\sin k\,\xi$$

Substituting for p from equation (3) gives

$$P_{wt} = 2 \text{ km.}\left(\frac{x}{s}\right)\left(\frac{A^2}{g}\right)H\,V^2\,\xi^2 \sin k\,\xi$$

$$= 2 \text{ km.}\left(\frac{xA^2}{sg}\right)H\left(\frac{V_i^2}{\sigma}\right)\xi^2 \sin k\,\xi \quad . \quad . \quad . \quad (4)$$

The stick force produced by the aerodynamic hinge moments of the ailerons, P_{ail} say, will be

$$P_{ail} = 2m.\ Kb_2.\ S_\zeta c_\zeta\ \tfrac{1}{2}\rho\ V^2\ v$$

$$= m.Kb_2.\ S_\zeta c_\zeta\ \rho\ o\ V_i^2\ \xi \quad . \quad . \quad . \quad . \quad (5)$$

Thus the overall stick force, P, from (4) and (5) may be written

$$P = m.Kb_2.S_\zeta c_\zeta\ \rho o\ V_i^2\xi + 2 \text{ km.}\left(\frac{xA^2}{sg}\right)H\left(\frac{V_i^2}{\sigma}\right)\xi^2 \sin k\xi \quad . \quad (6)$$

Unless the ailerons are overbalanced, Kb_2 is negative. The first term in the above expression is thus negative, while the second term is positive, representing the relieving force produced by the inertia device.

3. Illustrative Example.

We will take as an example an aeroplane of 600 sq. ft. wing area, representing a bomber of about the size of the Ju. 88. The following characteristics will be assumed:—

$S = 600$ sq. ft. $2s = 60$ft.
40%s x 25%c unsealed ailerons; total aileron area/wing area $= 0.07$.
As the ailerons are unsealed, equation (2a) gives $C_2 = 0.15$.
Stick gearing $= 3$ deg./inch. Maximum aileron angles $+25°$.
Aileron $Kb_2 = -0.05$. $\lambda = 0.8$. $l_p = -0.4$.

and the inertia device will be taken as fitted at 0.8s, with maximum angles $\pm 50°$ (i.e. $k = 2$).

In Fig. 2 stick force is plotted against aileron angle for various values of the weight moment, when flying at 250 m.p.h. corrected airspeed (V_i) at 15,000 ft. The utility of the scheme at once becomes apparent. A weight moment of only 20 lb. ft. in each wing will roughly halve the stick force for $\frac{3}{4}$ aileron, while 30 lb. ft. will give overbalance at full aileron dispacement.

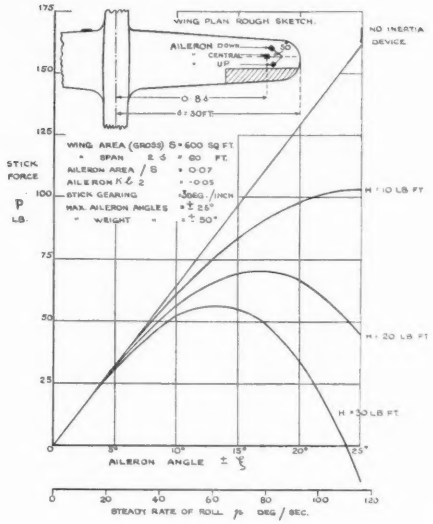

WING PLAN ROUGH SKETCH.
AILERON DOWN 30°
" CENTRAL 25°
" UP
0·84
47·30FT.
WING AREA (GROSS) S = 600 SQ FT.
" SPAN = 80 FT.
AILERON AREA / S = 0·07
AILERON K² = 0·05
STICK GEARING = 3DEG./INCH
MAX. AILERON ANGLES = ± 25°
" WRIGHT " = ± 50°
STICK FORCE P LB.
NO INERTIA DEVICE
H = 10 LB FT
H = 20 LB FT
H = 30 LB FT
AILERON ANGLE ± ζ
STEADY RATE OF ROLL p DEG / SEC.

FIG. A2.

Effect of Aileron Inertia Device on Stick Forces at 250 m.p.h. V_i at 15,000 ft.

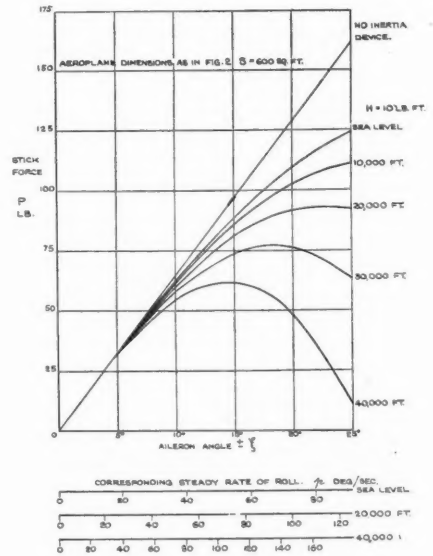


FIG. A3.

Variation with Height of Balancing Effect produced by Aileron Inertia Device at a given indicated Airspeed (V_i = 250 m.p.h.)

A study of equation (6) shows that at a given height the relative form of the curves in Fig. 2 is independent of airspeed; the ordinates of all the curves are proportional to V_i^2. Thus at 15,000 ft. the 20 lb. ft. weight moments will halve the stick force for $\frac{3}{4}$ aileron at all speeds, assuming kb_2 remains constant, and neglecting wing twist.

Alteration of height will, however, affect matters considerably. At a given V_i, the rate of roll per unit aileron displacement increases with height (since the applied rolling moment remains the same, whereas the damping moment, depending not on V_i, but on V, gets less). Thus *the balancing effect of an inertia device will, at a given* V_i, *become relatively more powerful at great heights.*

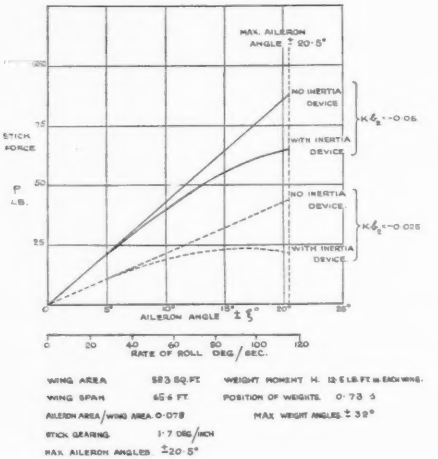


FIG. A4.

Ju. 88—Rough Estimate of Effect of Existing Inertia Device on Stick Forces at 250 m.p.h. V_i *at 15,000 ft.*

This is expressed mathematically in equation (6), where it will be seen that the first term is qualified by V_i^2, and the second (balancing) term by V_i^2/σ. In Fig. 3 stick force is plotted against aileron displacement for a series of heights from sea level to 40,000 ft., at $V_i = 250$ m.p.h., with a weight moment of 10 lb. ft. in each wing. The very marked increase with height of the balancing effect due to the weights should be noted, since this seems one of the main pitfalls attending the use of this device. If a designer produces a scheme to give a large degree of balance at sea level, he may find that the ailerons are grossly overbalanced at high altitudes. It is advisable, therefore, that rough calculations of the type just described should be done before fitting swinging weights to the ailerons of a new aeroplane, particularly if the aeroplane is designed for a high ceiling.

4. Ju. 88 Installation.

As mentioned in S1 the device under discussion is fitted to the Ju. 88, and the following details of the installation are of some interest:—

$W = 28{,}600$ lb. $S = 583$ sq. ft. $2s = 65.6$ ft.
Aileron area/wing area = 0.078.
Percentage balance = 27·7%.
Aileron span/wing span = 0.368.
Maximum angles = $\pm 20.5°$.

Aileron chord/local chord = 0.23.
Stick gearing = 1.7 deg./inch.
Aileron type: - slotted (wheel control).
The weights in the wings are 12 lb. at an arm of 1.04 ft. i.e. $H = 12.5$ lb. ft., and are located 24 ft. from the centre line, i.e., $x = 0.73$.
Maximum angles are $\pm 32°$, i.e., $k = 1.56$.

In the absence of tunnel data, only a rough estimate of the characteristics of the installation can be made. Stick force is plotted against aileron angle in Fig. 4, with and without the inertia device, for two assumed values of $Kb_2 - 0.05$ and -0.025; the curves apply to the aeroplane flying at 250 m.p.h. V_1 at 15,000 ft.

Pilots report that, for such a large aeroplane, the ailerons are remarkably light and effective at high speeds. The time to bank 45° at 240 m.p.h. A.S.I. at 3,000 ft. when the pilot applied the ailerons vigorously and held them on was measured. The surprisingly low figure of *0.6 sec. to 45° bank* was obtained; between $\frac{3}{4}$ and full aileron was applied, and the stick force was in no way excessive.

Since on a wheel type control an aileron force of more than 50 lb. would probably be considered heavy, it appears from the curves of Fig. 4 that the Ju. 88 designer has started off with very light ailerons, and has used the swinging weights to still further reduce the stick forces for large displacements. Kb_2 probably lies between -0.05 and -0.025, and the swinging weights reduce the force on the wheel needed to apply full aileron by something between 25% and 50%.

On the Ju. 88 the aileron hinge is below the aileron, so that when the aileron is displaced downwards, its C.G. moves aft. The swinging weight is so coupled that when the aileron comes down, the weight swings forward, thereby affecting a type of mass balance for fore-and-aft accelerations.

5. Discussion.

This device is mainly applicable to aircraft which may have to take very violent avoiding action, such as fighters and dive bombers. Essentially it provides a method, and on paper a very powerful method, of reducing the stick forces for *large* aileron displacements, thereby enabling an aeroplane to roll very quickly at high airspeeds. In this connection it may be noted that to exploit the full potentialities of the device, it should be used in conjunction with a light elevator, so that "*g*" can be put on readily as soon as the aeroplane has banked.

One great virtue of the scheme is its flexibility. The installation can be so designed for the prototype that the size of the weights, and their gearing to the ailerons, can be readily altered until the desired characteristics are obtained. In the course of such alterations, however, it is important that the effect of height (see Fig. 3) should be borne in mind.

A scheme of this sort should be of value in reducing the effect of the increase in hinge moment curve slope at large displacements often shown by highly-balanced controls.

Vote of Thanks.

Mr. N. E. Rowe (Fellow): In proposing a hearty vote of thanks to Mr. Morgan and Mr. Smelt, said that a great deal of their lecture had been of historical interest, and had served to indicate that perhaps aeronautical engineers and technicians did not sit down often enough to think over the knowledge they already possessed. Much of what had been said by the lecturers had come afresh to him, although, when thinking over it, he realised that he had known already a great deal of it. A consideration of the cooling problems which had been discussed, for instance, reminded them that they had tended to run into the same troubles as had the Germans, and one was a little shocked and surprised to recall that they had run into those troubles before the Germans had, and had obtained neat solutions.

Therefore, the lecture should prove to be very fruitful, and the meeting was fortunate in having the aerodynamic features of the German aircraft expounded by lecturers who were experts in their particular field of endeavour.

Mr. T. P. WRIGHT (Hon. Fellow): He and his Associates from America had been privileged to hear a most interesting lecture.

Commenting on one or two of the high spots of the subject, he said he had noted that the Germans had a greater allegiance to the slot than had the British. Secondly, Mr. Morgan had mentioned an interesting principle; it was always a feature of mechanical development that a great burden was placed upon the designer and the builder by making their job more complicated in order that the product of their labours should be less complicated for the operator to handle. In Mr. Wright's view, that was a proper trend.

The ingenuity which the Germans had shown in a number of the features demonstrated was quite remarkable. He had wondered whether the whole of the cowling and cooling arrangement on the B.M.W. 801 engine had been carried out by the airframe designer or the engine designer. Without knowing the answer, he ventured to suggest that probably it was done by the engine designer, for the responsibility for the power plant should rest upon the engine designer.

The fan cooling was particularly interesting, showing the trend in the improvement of power plant installations which was inaugurated some time ago by the engineers at Farnborough, to whom great credit was due in respect of the whole scheme of duct cooling, which was the initial step towards reducing the cooling drag to its present low proportion of the whole drag. They had prognosticated that in higher speed aeroplanes, and even at the speeds they were now approaching, there was no reason to believe that we could not derive actual thrust from that source.

It was indeed a privilege to second the vote of thanks to Mr. Morgan and Mr. Smelt for their very fine lecture.

R. T. YOUNGMAN (Fellow) contributed: He was only in agreement with Mr. Morgan's suggestion that designers in this country should follow the German example of improving control by mechanical devices when other and more simple means have been exhausted.

For example, when flaps are lowered and raised, the balance is affected by the change in the direction of flow and the change in centre of pressure. In stick free flight, the balance may still be further affected by automatic elevator movement. By careful balancing of the elevator this automatic elevator movement may be made use of to offset the effect of changes in downwash and centre of pressure without recourse to any mechanical coupling. An example of this is the Fairey " Fulmar " equipped with dive brake flaps. These flaps can be applied quickly at high speed hands off without any change in the flight path. With lift flaps it is preferable to aim at a slight nose downward movement of the aeroplane when the flaps are lowered and a slight upward movement when the flaps are raised. This characteristic follows automatically with the careful adjustment of b_1 and b_2.

He thought also that many apparent changes of trim or stick force might be traced to deformation of control surfaces with speed which might lend itself to improvement by metal covering.

He was particularly interested in the maximum lift coefficient of the Me. 109. A lift increment of 0.5 seemed to him rather a poor return for a combination of slotted flaps, drooped ailerons and wing tip slots when almost double this increment can be obtained in a far simpler manner without ruining the lateral control at slow speed.

Reply to Mr. Youngman:—

It is agreed that, ideally, aerodynamic solutions to problems of trim change with flaps and the like are preferable to mechanical gadgetry—gearing the flaps

to the tailplane, etc. In the present state of the art, however, the behaviour of the prototype sometimes confounds the aerodynamic prophets. Once the prototype has been built, altering its aerodynamics to reduce an unpleasantly large change of trim on, say, lowering the flaps can be a lengthy business. It is open to argument whether a mechanical approach is not preferable, as an insurance against lengthy development, since once the prototype is in existence the mechanics can be altered with rather more certainty than the aerodynamics.

With regard to the maximum lift coefficients of the Me. 109E, the overall increment in C_L max. of 0.5 on lowering the flaps, drooping the ailerons, and opening the tip slots is admittedly modest; much more could be obtained with such an arrangement by increasing the flap size, slot span, etc. In relation to the actual geometry of the layout, however, the measured increment is just about what would be expected.

REVIEWS.

Fogs, Clouds and Aviation.

By W. J. Humphreys. Williams and Wilkins, Baltimore. 1943. $3. (Baillière, Tindall and Cox, London. 1944. 16/6.)

The value of this book lies in its illustrations. Almost 100 photographs, of a technical beauty which suggests that they are the cream of a very large selection, show every type of cloud, besides other phenomena, such as the halo, corona, crepuscular rays and lightning.

The letterpress is disappointing. Obviously the author, as an official of the U.S. Weather Bureau, knows his subject through and through. Unfortunately he has thought it necessary to write down to his readers, and up to his idea of a poetical style. The result is irritatingly reminiscent of those " improving " books for children written towards the beginning of the present century. Revision by a competent journalist would be a great advantage to any subsequent edition.

Engineering Materials Annual.

Engineering Production Annual.

Edited by H. H. Jackson, A.F.R.Ae.S., M.I.E.I., etc. P. Elek, London. 8/6 net each. 1944.

These are the first two volumes of a series of Development Reference Annuals being published under the general editorship of H. H. Jackson. Their object is to give a concise and complete review of important development work carried out during the past year, with a bibliography of articles, lectures, etc. They are manuals to keep the engineer abreast with the latest developments.

" Engineering Materials Annual " covers in its various sections, each compiled by an expert, iron and steel and non-ferrous metals, rubber, ceramics, glass, plastics, fuels, oils, adhesives, plywood, etc. Each section is the briefest summary of technical development and research, together with the references not only to papers and the like, but recently published books on the subject.

" Engineering Production Annual " covers machine tools, deep drawing and pressing, surface protection and surface hardening, hard facing, soldering and brazing, powder metallurgy, cutting tools, cutting oils and compounds, welding, bearing metals, inspection methods and quality control, with the usual references.

The reviewer has always felt the importance of small reference books, published at regular intervals, giving the state of the art of engineering and science at that moment, so that students, research workers and others can have as recent knowledge as possible of what is being done and who is doing it. These annuals should prove invaluable for fulfilling that purpose. The information is compressed into a small compass, but most of it is there, and the very full references enable the expert to go as deeply as he may.

It is hoped that many other sides of engineering will be covered by these Annuals which should soon form a standard reference library.

British Aircraft (Vol. 1).

By R. A. Saville-Sneath. Penguin Books. 1944. 5/-.

Mr. Sneath has already written two " Penguins " on Aircraft Recognition. (Those handy paper-covered books have by now acquired the proper-noun status enjoyed by Tauchnitz in pre-war Europe.) Penguin Books now show us that

they can present a volume in more durable form, with the attraction of good paper, robust binding and a profusion of illustrations.

The present volume, although arranged as a recognition book, is not solely a collection of silhouettes of operational aircraft. It aims at giving a comprehensive survey of all aeroplanes built in Britain during the past ten years. Side by side with Mosquitoes and Manchesters we find our old peace-time friends—the Hawk, the Puss Moth, the Moth Minor, and other flying-club machines. In nearly every case the three-view silhouettes are amplified by photographs, most of them showing the aircraft in flying attitudes. A useful feature in the introduction is a summary of European history since the last war.

Volume 1 deals solely with monoplane landplanes. We are promised a continuation to include biplanes, gliders, seaplanes and rotorcraft.

GAS TURBINES AND JET PROPULSION FOR AIRCRAFT.

By G. Geoffrey Smith, M.B.E. Flight Publishing Co., Ltd. 1944. 6/- net.

This is the third edition of what must now have become an aircraft best seller, and deservedly so.

The recent release of information of jet-propelled aircraft work in this country and America has enabled the author to give credit to where real credit lies for the development of jet propulsion, Group Captain Frank Whittle. Secrecy precautions prevented it being stated in earlier editions that this country was leading the world in the new development, and that it was due to the genius and steady persistence of one man, an Englishman.

Now that some information has been released the author has been able to give a much fuller account of Whittle and his work, and of the parts played by W. G. Carter, Chief Designer of the Gloster Aircraft Company, and the late Flt.-Lt. P. E. G. Sayer, chief test pilot of the company.

YOUTH AT WAR. (Omnibus Volume.)

B. T. Batsford, Ltd. 1944. 15/-.

Messrs. Batsford have had the happy idea of reprinting three of their successful publications in a single volume: "Fighter Pilot," by Paul Richey; "Sub-Lieutenant," by Ludovic Kennedy; and "Infantry Officer," by Anthony Irwin.

We reviewed "Fighter Pilot" on its first anonymous appearance in 1941, so we will merely say that it remains one of the most vivid and personal narratives that have yet been written about the present war, and that we are glad to see it appear with the name and portrait of its attractive young author (who now holds the D.F.C. and Bar, with the French and Belgian Croix de Guerre).

Ludovic Kennedy, the "Sub-Lieutenant," is the son of the Captain of the "Rawalpindi." We are told in the Introduction that his pre-war ambition was to become a journalist, and he certainly has the journalist's knack of telling a good story and turning a neat phrase. ("Bad language is like vintage port, which should only be taken occasionally, when its value can be appreciated.") Particularly touching is his description of his father's pride and joy when recalled from his retirement to command the "Rawalpindi." Young Kennedy describes how, after seeing over the ship, he noticed its guns lying on the jetty. "These were the guns about which my father wrote later to a friend: 'They have given me some guns, good guns, and I am going to use them.' That was the last time I saw my father. But he used his guns all right." The narrative covers the Norwegian campaign, the Lofoten and Spitzbergen raids, and the sinking of the Bismarck. "I have seen tragedy in this war, and I have seen beauty: dawn breaking over the grey Atlantic waters; middle watches on the bridge, the foremast swaying gently against a background of stars; the battlefleet manœuvring; destroyers steaming into a head sea; Northern Lights over an Icelandic

fjord; the Lofoten Islands at daybreak. Those are sights which I shall never forget."

The third book, "Infantry Officer," is a slender narrative, some 40 pages long, covering the summer of 1940 up to the retreat from Dunkirk. The author, who won the M.C. during this campaign, shows the same qualities of courage, humour and commonsense as the Fighter Pilot and the Sub-Lieutenant, and these characteristics appear in his writing.

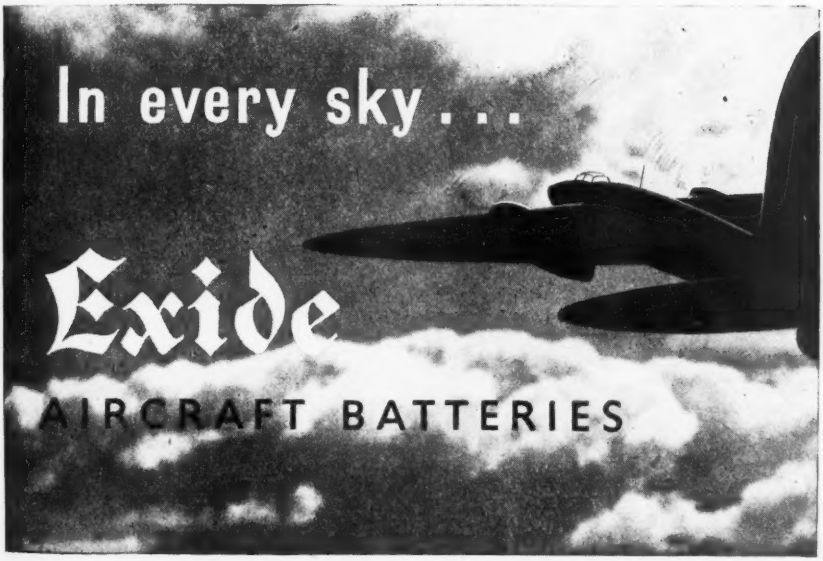
If, as we hope, these three young men are typical specimens of our "Youth at War," there is no need for older generations to worry about the future destiny of England. We hope this book will have a wide circulation in Allied and Neutral countries, for it throws more light on the English character than any amount of propaganda could do.

AIRCRAFT MECHANIC'S POCKET BOOK.

By John T. Henshaw. Sir Isaac Pitman & Sons. 1944. 2/6.

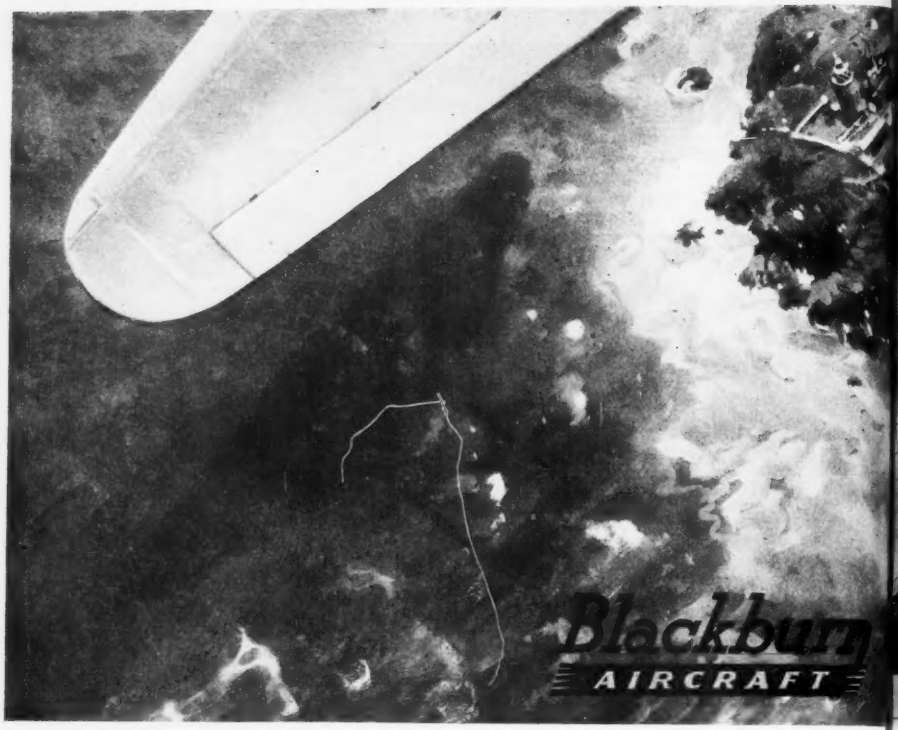
This slim volume, just the right size to slip into the breast-pocket of dungarees, contains a great deal of practical information: Tables of Specification Numbers; data on Sheet Metal Work, Drilling, Tapping and Reaming, Tolerances, Rivets, Welding (with notes on safety precautions), Anti-Corrosion Treatments, Heat Treatment and Tempering, Bolts and Nuts, the fixing of Transparent Plastic Panels, Cables and Cords, Timbers and Adhesives. The last few pages are devoted to mathematical data, trigonometrical functions, and conversion tables.

The "FULMAR"
The Fulmar petrel is found around Britain's northern shores, and elsewhere. Of recent years its numbers have tended to increase.
Although gull-like in general appearance, its flight is distinctive.
FAIREY AIRCRAFT



THE CHLORIDE ELECTRICAL STORAGE COMPANY LTD
Grosvenor Gardens House. Grosvenor Gardens, London, S.W.1

W. MSC 76B/43



MORRISONS
CROYDON

AIRCRAFT CONSTRUCTION
MAINTENANCE AND REPAIR

Smee's

Dunelt
Special Steels
FOR AIRCRAFT

CASE HARDENING STEELS
STAINLESS STEELS
HIGH TENSILE ALLOY STEELS
Conforming to all Air Ministry and B.S.I. Specifications.

DUNFORD & ELLIOTT (SHEFFIELD) LTD.
Attercliffe Wharf Works - - Sheffield 9.
Grams: "Blooms, Sheffield" Phone: Attercliffe 41121
London Office: 54 Victoria Street, S.W.1.
Birmingham Office: 25 Burlington Chambers, 11B New Street.

AIR NAVIGATORS

Makers of all types of Protractors for nearly thirty years, we are producing the celebrated "DOUGLAS" Protractor in ever increasing quantities. The "DOUGLAS" Protractor is indispensable to all navigators, supplied in two sizes, 5" and 10" square.

The "MACLEAN" D.R. (Dead Reckoner) Protractor of new design is now in full production. Designed primarily for Air Navigation, it is simple to use and serves as a constant reminder of essential data.

For further particulars of these two instruments and all other navigational aids, write for our illustrated brochure to

LONDON NAME PLATE MANUFACTURING CO. LTD.
EYLO WORKS BRIGHTON 7

29 AERONAUTICAL FIRST PLACES

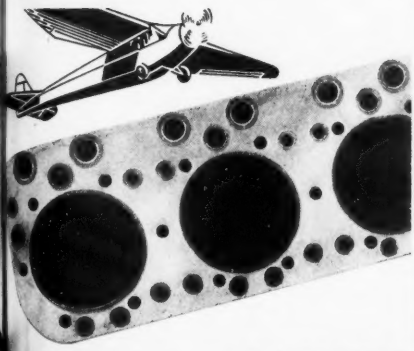
Your Best Guide to Successful Courses

Recent T.I.G.B. Successes A.F.R.Ae.S. Examination

1943—FIRST PLACE, AERODYNAMICS
1943—FIRST PLACE, AIRCRAFT DESIGN
1943—FIRST PLACE, APPLIED MATHS.
1942—BADEN-POWELL MEM. PRIZE
1942—FIRST PLACE, AERODYNAMICS
1942—FIRST PLACE, AIRCRAFT DESIGN
1942—FIRST PLACE, APPLIED MATHS.
1941—BADEN-POWELL MEM. PRIZE
1941—FIRST PLACE, I.C. ENGINES
1941—FIRST PLACE, AERO ENG. DES.
1941—FIRST PLACE, APPLIED MATHS.

Write TO-DAY for "The Engineer's Guide to Success"—Free—containing the world's widest choice of engineering and aeronautical courses—over 200—including **Aeronautical Engineering; Aircraft Design; Aeroplane Structures; Aircraft Construction; Aero Engine Design, Construction, Operation and Maintenance; Aerodynamics; Aerial Transport; Aerial Navigation; Meteorology; Aircraft Materials, etc.**, and which alone gives the Regulations for Qualifications such as **A.F.R.Ae.S., Ground Engineer, Air Navigator, A.M.I.Mech.E., A.M.I.E.E., C. & G., etc.** The best guide to **R.A.F. Entrance and Technical Courses.** The T.I.G.B. guarantees training until successful.

THE TECHNOLOGICAL INSTITUTE OF GREAT BRITAIN
39, Temple Bar House, London, E.C.4.



All Metal GASKETS

Corrujoint Gaskets are the choice of many leading aero-engine manufacturers. Made of a single sheet of corrosion resisting metal, with a corrugated face to ensure a perfect seal, they eliminate blowing and cracking. High temperature and pressures cannot damage Corrujoint.

Details and Quotations sent on Request.

THE CORRUGATED PACKING AND SHEET METAL CO. LTD.
GATESHEAD-ON-TYNE-ENGLAND
TELEPHONE 71785 GATESHEAD • TELEGRAMS CORRUJOINT GATESHEAD

The PATENT UNIVERSAL BALL JOINTS

For all types of Remote Control, Accessory Drives, Etc., Efficiency 98% Max., 92% Min. N.P.L. Certified. The lightest and most compact Joint made

The MOLLART ENGINEERING CO. LTD.
PRECISION ENGINEERS

Kingston-by-pass, Surbiton, Surrey. Phone: Elmbridge 3352/3/4/5. Grams: Precision, Surbiton.

Air Ministry Approved Gauge Test House: No. 89755/31

INDEX TO ADVERTISERS

Aeroplane and Motor Aluminium Castings, Ltd.	xxii
Angus, Geo., & Co., Ltd.	ii
Armstrong Whitworth, Ltd.	xiii
Automatic Coil Winder & Electrical Equipment Co., Ltd.	xiv
Automotive Products, Ltd.	vii
Bakelite, Ltd.	ii
Birkett, T. M. & Sons, Ltd.	xii
Blackburn Aircraft, Ltd.	xx
Booth, James, & Company Ltd.	xxiii
Bristol Aeroplane Co., Ltd.	*Back Cover*
Bunhill Publications, Ltd.	xvii
Cellactitie & British Uralite Co., Ltd.	x
Central Chemicals, Limited	xviii
Chloride Electrical Storage Co., Ltd.	xix
Corrugated Packing & Sheet Metal Co., Ltd.	xxi
Dowty Equipment, Ltd.	ix
Dunford & Elliott, Ltd.	xx
English Steel Corporation, Ltd.	xxii
Fairey Aviation Co., Ltd.	xix
Ferodo, Ltd.	viii
Firth, Thos. & Brown, John, Ltd.	xviii
Firth-Vickers Stainless Steels, Ltd.	vii
The Heywood Compressor Co. Ltd.	xiv
High Duty Alloys, Ltd.	xi
Hoopson, H. M. (Aircraft & Motor Components), Ltd.	xv
Hughes, F. A. & Co., Ltd.	iv
Hiduminium Applications Ltd.	v
I.C.I. Plastics	xiv
International Alloys, Ltd.	ix
Iablo Propellers, Ltd.	xiii
Leytonstone Jig and Tool Co., Ltd.	viii
Lodge Plugs, Ltd.	xv
London Name Plate Co., Ltd.	xxi
Macrome, Ltd.	xxiii
Magnesium Castings & Products, Ltd.	iii
Mollart Engineering Co., Ltd.	xxi
Morrisons Eng.	xx
Napier, D. & Son, Ltd.	xvi
Newall, A. P. & Co.	*Back Cover*
Pitmans	ii
Roe, A. V. & Co., Ltd.	xviii
Rolls-Royce, Ltd.	v
Rotax, Ltd.	vii
Rotol Airscrews, Ltd.	xii
Sangamo Weston, Ltd.	xvi
Smith's Aircraft Instruments, Ltd.	xi
Technological Institute of Gt. Britain	xxi
Vickers Armstrongs, Ltd.	iii
Vokes, Ltd.	x
Westland Aircraft, Ltd.	xv
Wickman, A. C., Ltd.	vi
Warwick Aviation Co., Ltd.	iv
Wilkinson Rubber Co.	vi
Yorkshire Engineering Supplies, Ltd.	xvii

HIGH CLASS ALUMINIUM SAND CASTING

Produced by—
AEROPLANE & MOTOR ALUMINIUM CASTINGS LTD.
WOOD LANE,
ERDINGTON,
BIRMINGHAM, 24

Suppliers of Aluminium and Magnesium Alloy Die and Sand Castings of every description.

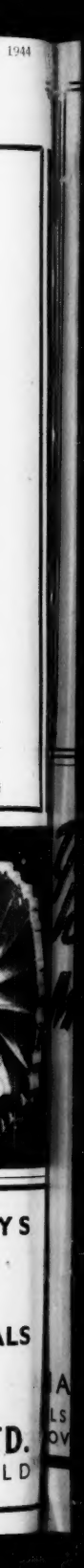
ESC

CARBON AND STEEL ALLOYS
OF THE HIGHEST QUALITY

FORGINGS, CASTINGS
DROP FORGINGS, RAILWAY MATERIALS

Small Tools and Tool Steels

ENGLISH STEEL CORPORATION LTD.
VICKERS WORKS SHEFFIELD


1944

Telephone: EAST 1221.

James Booth & Company, Ltd.
Birmingham, 7

PIONEER MANUFACTURERS
IN GREAT BRITAIN OF
STRONG ALUMINIUM
AND
MAGNESIUM ALLOYS

DURALUMIN ALDURAL DURAL
REGISTERED TRADE MARK REGISTERED TRADE MARK REGISTERED TRADE MARK

M.G.7
REGD. TRADE MARK

"ELEKTRON"

You've got to hand it to-
MACROME

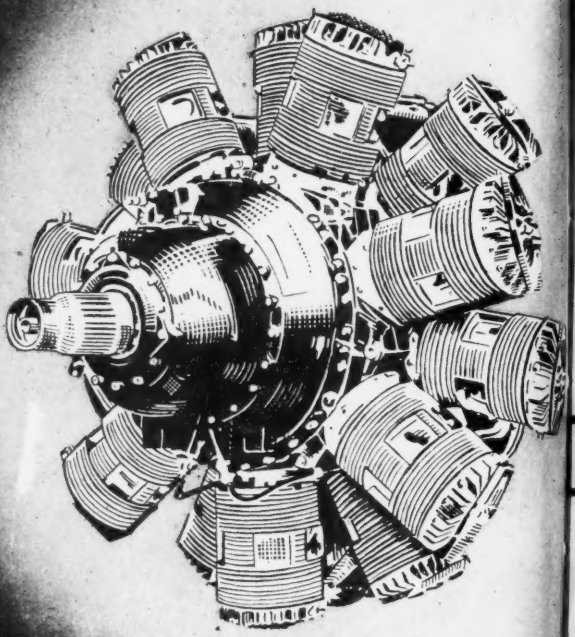
for tools that will really finish the job!

MACROME LIMITED, ALCESTER, WARWICKSHIRE
ALSO AT LONDON · GLASGOW · MANCHESTER · LEICESTER · LEEDS
COVENTRY · BRISTOL · NEWCASTLE-ON-TYNE · BIRMINGHAM · BASINGSTOKE

Britain's — Power in the Skies....

AIR-COOLED RADIAL ENGINES by

"Bristol"



THE BRISTOL AEROPLANE COMPANY LIMITED. BRISTOL

Newallastic

WE have received many enquiries with regard to the physical properties of "NEWALLASTIC" bolts and studs. They have a tensile strength of 65/75 tons, with an elongation of 15% and upwards, and a reduction in area of 55/60%.

Owing to the patented process by which they are manufactured, they have a greater resistance to fatigue than any bolts or studs hitherto obtainable.

The threads are produced by an entirely new method and are almost as accurate as the finest gauges.

"NEWALLASTIC" Bolts and Studs are the last word in STRENGTH AND ACCURACY.

A. P. NEWALL and CO., LTD.

POSSILPARK. GLASGOW. N.

Printed by the Lewes Press (Wightman & Co., Ltd.), Friars Walk, Lewes, England, and Published by the Royal Aeronautical Society, 4, Hamilton Place, London, W.1, England.